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MANUAL FOR DEICING CHEMICALS

STORAGE AND HANDLING

Arthur D. Little, Incorporated

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3. Environmental responsibilities are discussed for personnel who administer and supervise highway maintenance.

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By

David L. Richardson
Project Director

Charles P. Campbell
Raymond J. Carroll
David I. Hellstrom
Jane B. Metzger
Philip J. O'Brien
Robert C. Terry
Arthur D. Little, Inc.
Cambridge, Massachusetts 02140

Contract No. 68-03-0154
Program Element No. 1BB034

Project Officer

Hugh E. Masters
Storm and Combined Sewer Section (Edison, N.J.)
Advanced Waste Treatment Research Laboratory
National Environmental Research Center
Cincinnati, Ohio 45268

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment -- air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The study described here was undertaken to minimize the loss to the environment of chemicals used in controlling snow and ice on highways. Practical guidelines are presented for good practice in the storage and handling of deicing chemicals.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

This report contains the results of a study conducted for the U.S. Environmental Protection Agency to minimize the loss to the environment of chemicals used in controlling snow and ice on highways. Based on the best current practices for highway maintenance as observed during two years of study, practical guidelines are presented for good practice in the storage and handling of deicing chemicals.

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This report was submitted in partial fulfillment of Program Element 1BB034 Contract No. 68-03-0154 by Arthur D. Little, Inc., under the sponsorship of the Environmental Protection Agency. Work was completed in March 1974.

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SUMMARY AND RECOMMENDATIONS

Each year state highway departments, turnpike authorities, municipal street departments, and other organizations (shopping centers, hospitals, schools) purchase approximately 9,000,000 tons (8,200,000 t)* of salt and other deicing chemicals with a total value of about $140,000,000.

From the time these chemicals are ordered to the time they are spread on highways and parking lots, they undergo several rounds of handling and storage. First, they are delivered from the mine, salt-producing facility, or port of entry to regional distribution points. From there, they are distributed (usually by truck) to highway maintenance yards. Finally, they are loaded onto spreader trucks for their final use during storms.

At each step of the journey from mine or salt-producing facility to highway, there are numerous opportunities for loss of material. At any of the storage points, salt exposed to weather is dissipated into the immediate environment by rain and wind. Rain will reduce a salt pile at the rate of about 1/4% per annual inch of precipitation.[1] That figure may appear insignificant, but in an area with 40 in. (101 cm) of precipitation each year, a salt pile left exposed for half a year will lose 5% of its volume. An exposed salt pile of 500 tons (450 t) would lose 25 tons (23 t) under these conditions, not counting losses due to wind.

Loss of material provides cause for several kinds of concern. Chief among these, from the standpoint of the Environmental Protection Agency, is the concern for environmental damage that may result from water- and wind-borne salt. In Massachusetts, for example, seepage from storage piles has contaminated town water supplies. The 25 tons (23 t) of salt carried off the 500-ton (450-t) salt pile cited above is sufficient to pollute almost 15 million gal. (56.7 million l) of water to the 250 milligrams per liter (mg/l) chloride maximum recommended by the U.S. Public Health Service for drinking water supplies. Water of even lower salinity has been known to cause corrosion problems in industrial plants. That same 25 tons (23 t) of salt runoff is capable of raising the sodium content in almost 120 million gallons (454 million l) of water to threshold level (20 mg/l) beyond which it becomes dangerous to medical patients restricted to low-sodium diets.

Cost is another area of concern. Although the direct cost to a highway agency of losing 25 tons (23 t) of salt over a season is only about $400-$500, there are additional indirect costs. These indirect costs are borne partly by the agency, in the form of corrosion damage to equipment in the yard, but mostly by other segments of the public. It is very difficult to calculate the total damage caused by salt runoff, partly because the effects are dispersed and partly because of the problem of placing a monetary value on the deterioration of public health resulting from sodium- and chloride-polluted drinking water.

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* Throughout this report metric units are given in parentheses.

Because of hazards posed by salt stored in exposed piles, this manual's recommendations on salt handling practice in Part Three are based, except as noted, on the presupposition that salt will be stored in permanent buildings. As the data in Part Two, (which describes storage facilities) indicates, fixed storage is not wholly uneconomical. The annual value of salt saved by protecting it from the weather is sufficient over a period of ten to forty years, depending on annual precipitation and construction costs and methods, to offset much of the cost of a storage building.

THE INTENT OF THIS MANUAL

This manual aims at establishing an operational balance between two important, but sometimes conflicting, public-policy goals--clear roads and clean water. Keeping highways and roads clear in winter is vital to the nation's commerce and to the safety and convenience of the traveling public, and the most effective and economical deicing material is sodium chloride--ordinary salt, sometimes mixed with calcium chloride or sand. Salt runoff from highways and storage areas mixes with surface waters, and in dilute form either enters streams and lakes or seeps into the ground. Depending on conditions of surface and soil, salt runoff may seriously degrade the quality of the receiving water.

Protection of the environment is the primary concern of the U.S. Environmental Protection Agency. Recognizing that the nation cannot afford to pursue a goal of clear winter roads to the exclusion of concern for water quality, or vice versa, the EPA has commissioned studies for the purpose of establishing the best practices for balancing the goals of clear roads and clean water. The results of these studies appear in two manuals: a Manual for Deicing Chemical Application Practices (EPA-670/2-74-045) which recommends salt-application methods and maximum usage levels for various storm and temperature conditions; and this document, a Manual for Deicing Chemical Storage and Handling.

This manual is written for people who are directly concerned with the storage and handling of salt. State and municipal officials will be concerned with the initial capital-cost, environmental, and land-use aspects of storage and handling and with possible later costs resulting from damage to water supplies, as well as with public sentiment. Public works administrators and yard foremen, who have the day-to-day responsibility for storing and handling salt, will be concerned with the details of site construction, loading and unloading, storage, and covering piles. Operators of large non-highway installations that have large paved areas to keep clear in winter (parking lots and driveways) need to be concerned with both policy and operational aspects of salt handling and storage.

The manual is intended to be, above all, practical. Its recommendations are based on the best of current practice, as observed during many weeks spent with highway crews in snow-belt states. The recommendations recognize that snow conditions, storage site availability, and budgets vary widely. Exotic solutions requiring large capital outlays and special equipment are avoided. The manual covers the following areas:

Part One: Administration and Supervision
I. Supervision Requirements
Part Two: Storage Facilities
II. Site Selection
III. Foundation and Working-Area Design
IV. Design of Storages
Part Three: Handling of Deicing Chemicals
V. General Precautions in Handling
VI. Planning for Next Season
VII. Receiving and Storing Deicing Chemicals
VIII. Loading Chemicals for Use

Much of what this manual advocates is already recommended practice. In recent years, salt has been stored increasingly under some protective cover, whether a tarpaulin or a roof, and on sloped impermeable pavements rather than on the bare ground. Design and operating practice found in this manual are based upon, or direct borrowings of, plans and descriptions reported by highway personnel, the Salt Institute, and researchers in publications including state maintenance manuals; papers presented to the Highway Research Board, the North American Snow Conference, the American Public Works Association, and other technical and professional associations; and corporate and institutional publications.

What, then, is the unique contribution of this manual? Probably, it is valuable in several ways:

- *Range*. The manual covers all aspects of storage and handling, from the estimation of storage requirements to the public-policy implications of salt storage.

- *Balance*. The manual concerns itself equally with operational and environmental issues.

- *Perspective*. The manual draws upon a range of literature, as well as first-hand observation of storage and handling operations.

- *Alternatives*. The manual presents a procedure whereby its users can derive operationally and environmentally satisfactory solutions that are suited to their particular needs and constraints.

In short, this manual aims at providing a complete, sensible, usable, down-to-earth guide to the problems and issues connected with salt storage and handling.

Many states and municipalities will undoubtedly wish to establish laws or regulations for ensuring the proper handling and storage of salt. While this manual does not offer a "model code," the remainder of this summary contains the essential points that should be included in codes or regulations. These points are classified under three headings corresponding to the three Parts of this manual: Administration and Supervision, Storage Facilities, and Handling of Deicing Chemicals.

ADMINISTRATION AND SUPERVISION

Responsibility for the Environment

Components of Supervision. Supervising maintenance engineers, in addition to their expected competence in engineering and administrative areas, should also be knowledgeable about the following topics:

- Basic principles of groundwater hydrology

- Emerging federal and state environmental and land-use policy

Organizational Location. Environmental responsibility should be located at the field-office level. Each field office should have one specialist who has clear responsibility for environmental matters. This specialist should be able to call upon the technical expertise resident in other state or local agencies as needed.

Supervision Requirements

Job Description. The following responsibilities should be added to the descriptions of supervisory maintenance engineers or specialists with environmental responsibilities:

- Design and ensure proper use of system for reporting usage of deicing chemicals.

- Review and interpret periodic salt use reports.

- Schedule ordering and delivery of salt so as to minimize risks of salt runoff.

- Identify and select sites for salt storage facilities.

- Supervise design and preparation of storage-facility plans and specifications.

- Cooperate with other government agencies on environmental and public health aspects of storage.

- Ensure proper maintenance of storage through training and on-the-spot inspection.

Supervisory Training. Supervising maintenance engineers should participate in occasional in-service training courses. Topics covered should include groundwater hydrology; environmental aspects of planning, design, and construction; and procedures for complying with federal and state environmental law.

STORAGE FACILITIES

Site Selection

Basic Siting Methodology. Several possible storage sites should first be identified according to their ability to satisfy operational requirements (site size and topography, proximity to service area). These sites should then be screened to find the one that best conforms to environmental criteria: geologic and hydrologic, biologic and ecologic, and historical and aesthetic. The selected site should then be designed to mitigate any remaining potential for environmental damage.

Operational Requirements. Deicing chemicals should be stored near the center of the road section area, close to a major right-of-way. Storage sites should be close enough to permit a truck to reach the boundary of the next section and return before exhausting 90% of its load. Storage sites should have enough space for structures containing 50-100% of the seasonal requirements for chemicals and treated abrasives. If possible, storage sites should be located on rail sidings to permit direct receipt of chemicals.

Geologic and Hydrologic Criteria. Basic information about the terrain underlying a potential site should be sought as part of the site location process. Particularly to be avoided is a site location in an aquifer recharge area, where salt seepage may pollute wells.

Biologic and Ecologic Criteria. Species differ in salt tolerance. The best way to prevent damage to flora and fauna is through proper design of storage sheds and good housekeeping practices.

Historical and Aesthetic Criteria. An inventory of potential sites should consider whether any are exposed to "landmark" areas.

Site Vulnerability Analysis. Priority should be given first to protection of water supplies--groundwater and surface water. Next, attention should be given to preserving a site's historical or aesthetic character.

Foundations and Working-Area Design

Prerequisites to Foundation Design. Factors to be taken into account in foundation design include topography (siting and shed pad higher than surrounding terrain to prevent run-in), soil and subsurface conditions, frost penetration and snowfall, type and layout of structure with respect to dead and live loads, applicable building codes, requirements of material handling operations, and aesthetics.

Foundation Design Considerations. Foundations must be designed to withstand lateral loading by stored salt. Continuous walls or buttress walls may be used. For either type, reinforced concrete or its strength-equivalent should be used. The floor slab inside the building should be made of impervious material. A minimum floor covering calls for 2.5-in. (6-cm) bituminous concrete on a 6-in. (15-cm) compacted gravel base.

Working Area Design. Working area must be designed to prevent brine runoff into environmentally sensitive areas. In areas with particularly vulnerable water supplies, all brine runoff must be contained in a lined collection basin from which brine is pumped out for removal to a nonsensitive area.

Design of Storages

Environmental Requirements. Storages should protect chemicals from direct precipitation at all times, keep the material within prescribed bounds, and not leak or burst as a result of accidents.

Functional Requirements. Storages should be large enough to hold 50-100% of seasonal requirements without overflowing, not require special handling procedures for rapid loading, allow enough vertical clearance for delivery trucks and raised loader buckets, allow for maneuvering room for loaders, and be reinforced or protected at key points.

Arrangement within Operations Area. Several different kinds of storage areas have different characteristics. Major distribution areas receive chemicals by rail or boat and distribute it usually within a 50-mile (80-km) radius; storage may exceed 100,000 tons (91,000 t) under tarpaulins or reinforced plastic film. Highway area is measured in "lane miles" or miles of traffic lanes. Thus a one-mile stretch of a two-lane road measures two lane miles. District base areas usually serve 1500 or more lane miles (2400 lane km) and have repair and garage facilities; covered storage should be provided for up to 3,000 tons (2,700 t) of chemicals and for treated abrasives when used in the snow and ice control program. Crew areas typically service about 100 lane miles (160 lane km) of road and require covered storage for up to 1,500 tons (1,400 t) of chemicals and for storage of treated abrasives. Reload areas, located near the dividing line between two crew areas, require covered storage for about 500 tons (450 t) of chemicals and for storage of treated abrasives. Both crew and reload areas should provide a ramp for loading spreader trucks.

Good Practice in Salt Storage

Good practice requires a building that meets both functional and environmental requirements in the most economic manner. Numerous building types described in the manual, already in use, fulfill these requirements. Notable features of these sheds should be emulated whenever possible:

- Shield truck-loading operations from prevailing wind and weather (indoors whenever possible);
- Be secure to prevent accidents to youthful trespassers;
- Have floor and paving sloped to drain any water out of the shed and away from the salt pile;
- Have sufficient bituminous concrete pad around the exterior to allow free circulation of trucks and loaders;

- Offer protection to parts of the structure exposed to loading operations;
- Have galvanized metal hardware and building elements to prevent corrosion;
- Be adequately ventilated, particularly for indoor loading and unloading operations;
- Have ample lighting both indoors and out-of-doors to permit nighttime operations;
- Use durable materials that require minimal maintenance.

Other Storage Practices. Salt is sometimes stored in covered piles, overhead hoppers, and converted grain silos. Each of these alternatives has problems. Covered piles require exceptional measures in housekeeping to prevent salt-brine runoff. Overhead hoppers are convenient and reliable, but offer limited capacity at relatively high cost. Converted silos have limited capacity and are subject to problems of salt cakes jamming their mechanisms.

HANDLING OF DEICING CHEMICALS

General Precautions

Three major precautions should be observed during handling of bulk deicing chemicals:

1) Keep the chemicals dry, preferably in permanent covered structures.
2) Keep the handling area and equipment clean.
3) Keep to a minimum the number of times the materials are handled.

Careful attention to these precautions will ensure that the chemicals do not cake up and cause problems in handling and spreading and that exposure to the environment is minimized.

Planning for Next Winter

Planning for the next winter should be done immediately after the present winter season, while memories are fresh.

Pre-season Inventory. On the basis of recent experience, an assessment of the adequacy of chemical quantities ordered, equipment, and personnel complement should be made. Steps should be taken to correct deficiencies.

Equipment Used in Handling. Most maintenance yards use front-end loaders for moving bulk chemicals. Other possibilities include bulldozers, material throwers, and conveyors. The front-end loader is preferred because it is relatively trouble-free and may be used for many jobs during the remainder of the year.

Estimating Quantities. Establishing the amount of chemicals needed for next season's snow and ice control program should take into account the amount used during the past season, adjusted to account for changes in the number of road miles for which the yard is responsible or in the recommended level of usage (tons/mile or t/km).

Ordering and Scheduling. It is recommended that a minimum of a half year's, and preferably a whole year's, supply of salt be stored at each field station, and that deliveries be so scheduled that the season's supply is in storage by early October.

Receiving and Storing Deicing Chemicals

Putting Materials Under Cover. Salt should be delivered in fair weather and put under cover immediately. The equipment and the unloading area should be cleaned thoroughly at the end of the day. Similar precautions should be observed for calcium chloride and for mixtures (sodium/calcium chloride, sand/salt).

Specifications and Tests. Sodium chloride delivered in bulk should conform when delivered to ASTM Standard Specifications for Sodium Chloride D632. Calcium chloride should conform to ASTM D-98. Materials when received should be tested for conformity to these specifications and for the presence of anti-caking agents.

Loading Chemicals for Use

Trucks or spreaders should be loaded, if possible, inside the storage shed. Trucks should be cleaned of loose salt before leaving the loading area. If trucks are loaded outside the shed, the loading area should be cleaned as soon as possible after the truck leaves. Spilled material should be placed on the face of the pile so that it is loaded onto the next truck.

PART ONE: ADMINISTRATION AND SUPERVISION

CHAPTER I

SUPERVISION REQUIREMENTS

The many suggestions set forth in this manual depend for their effectiveness, of course, upon the cooperation and outlook of hundreds of highway department employees. They take their cues, in both technical and policy matters, from their supervisors who, even to the top level, must clearly endorse and support a policy of safe salt storage and handling. These cues should be explicit and unequivocal. This section points out those aspects of proper salt storage and handling where supervision is crucial.

Although a number of specific comments and recommendations are made below, one general point should precede the discussion. Leadership in general, and supervision of salt storage and handling, which is merely one aspect of highway maintenance, is by its nature not a separate commodity or function. It cannot be bought in packages. It cannot be contracted out. It is not the task of one man only; nor is it a full-time task performed by a staff specialist. Instead, responsibility for salt storage and handling is only one of the many assignments of maintenance supervisors. Ideally, they should be knowledgeable about a number of specific topics, to be described below. These are topics relatively new to highway officials, the result of rising environmental consciousness during the past several years and, therefore, not part of the standard curriculum. As a result, busy supervisors at the middle and top levels are likely to learn these topics on the run.

Therefore, detailed knowledge is probably less important than proper attitudes. To store and handle road salt safely requires many "tradeoff" decisions, balancing such goals as economy and efficiency against such goals as safety of public water supplies. In specific siting decisions, answers are not likely to come easily or quickly. Hence, maintenance supervisors must first be sympathetic to the general goal of environmental protection, as well as to the general goal of building and maintaining good highways, and then apply common sense and good judgment to making progress toward both goals.

In sum, good practice in salt storage and handling requires various kinds of technical knowledge. But in the end, probably the most important factor is responsible and sensible leadership by maintenance supervisors.

RESPONSIBILITY FOR THE ENVIRONMENT

Components

In addition to specific engineering and technical knowledge, maintenance supervisors should also have detailed knowledge about several topics bearing upon the environmental aspects of storage sites.

First is the set of environmental impact requirements of federal, state, and local authorities. Details vary from jurisdiction to jurisdiction, but the general purpose is to require consideration of side effects or secondary consequences of proposed projects on the environment.

Although actual environmental impact statements may be required in only rare cases for salt-storage facilities, the kind of decision-making displayed in an impact statement should be followed in construction and enlargement of salt storage facilities. This both ensures environmentally sound decisions as well as provides the basis for an environmental report, should one ever be required. As of March 1974, the current guidelines for environmental impact studies issued by the President's Council on Environmental Quality were published in the Federal Register Vol. 38, No. 147, August 1, 1973. State and local regulations pertaining to environmental planning and possible environmental impact statements should be consulted as well for guidance.

Second, supervisors must be familiar with the main principles of groundwater hydrology, at least enough to know when to call for help from specialists in this field. Taking care to site storage sheds far from surface waters is not enough. Underground seepage and flows must also be considered in relation to possible drainage of brine from a proposed storage site.

Third, supervisors should also be aware of possible requirements of emerging state land-use policies. At this writing, early 1974, the topic is too new to allow useful detailed statements. However, it is clear that concern about improving our usage of land, for both environmental as well as developmental purposes, is rising at both the federal and state levels. Therefore, it seems likely that, in time, state and local authorities will be adopting new and stricter criteria governing land use, about which highway engineers will have to become familiar.

These comments are phrased in terms familiar to state and county-level highway maintenance personnel. They apply with equal force, however, to engineers and turnpike authorities responsible for maintenance of roadways for private organizations as well, including hospitals, universities, schools, cemeteries, and commercial establishments such as shopping plazas and truck depots. In time, all may find themselves regulated to greater or lesser degree by state or local laws seeking to prevent further salt contamination of the environment, especially public drinking water supplies.

Clearly, many problems can be either created or solved when one is deciding where to site salt storage sheds. In many or most cases, especially in settled areas with existing highways or roads, these decisions have been made already; the problem may be, therefore, only how to improve upon the existing facilities and system. However, where new roads or highways are to be constructed and associated storage sites to be chosen, supervising engineers must be sure that proper siting requirements are considered early, during the planning and design stages.

In many departments, the functions of planning, designing, and maintenance are organizationally distinct, thus posing problems of coordination. For this reason, top-level engineers, with responsibilities for supervising all of these activities, should be sufficiently aware of the principles of proper storage to ensure that appropriate coordination at an early stage does in fact occur.

ORGANIZATIONAL LOCATION

The nature of the problem of siting and constructing storage sheds requires that a Department's environmental capability be located at the field office level, "where the action is," rather than only at a distant central headquarters. Each field office, district or division, probably cannot have an engineer specializing full time in storage problems. However, each field organization should have one person who is clearly designated with responsibility for environmental problems, who should play a significant role in decisions about siting, designing, and constructing storage facilities.

The designated environmentalist in an agency's field office should expect to, and be able to call upon environmental specialists from the state headquarters staff. A likely possibility in the immediate future would be for the state Department of Transportation or Department of Public Works, whichever the organization, to request such expertise, for example in groundwater hydrology, from another state agency concerned with natural resources or environmental protection.

To facilitate interagency cooperation, it is desirable that the field area of the highway agency have the same boundaries as the field area of environmental agencies. For example, a highway district may be responsible for constructing a road, with associated maintenance facilities, across two watersheds for public drinking water supplies. If each watershed is the responsibility of a different environmental protection field office, then the highway district's environmental specialist must negotiate with two instead of one counterpart, with resulting delays and complications. Although the designation of field district boundaries is a decision resting with the top levels of two or more state agencies, and further it is a decision involving many factors beyond the scope of this manual, it is still mentioned here as a factor that bears upon the siting of salt storage facilities.

As noted above, planning, design, and construction are often separate functions. Just as they must, therefore, be coordinated in general by top-level supervisors, detailed aspects of their work should be coordinated in fact at the field level by the environmental specialist, acting on the authority of the field office head, for example the District Engineer.

In smaller jurisdictions such as cities or towns or some counties, these different roles might not be required. Environmental aspects of salt storage should be the responsibility of the central public works office, or perhaps even of the chief engineer or highway superintendent.

JOB DESCRIPTION

Since no distinct full-time job centering on salt storage facilities is envisioned, no full job description for the environmental specialist is set forth. Instead, those environmental engineering aspects are indicated which should be added to present job descriptions of maintenance supervisors.

1. Identify and select sites for salt storage facilities, meeting environmental as well as engineering requirements and drawing upon expert assistance as necessary from headquarters staff.

2. Develop, or assist in the development of, environmental baseline data required for planning and possible environmental impact statements. Essential baseline data would include groundwater information and annual reports of its sodium and chloride levels (expressed in mg/l). Without such baseline data as a background, effects of various management practices, for good or for bad, cannot be measured objectively. Just as a planning or design engineer inventories materials, reports, etc., the environmental specialist should gather these data of importance in the environmental aspects of engineering decisions, much of it from other governmental agencies.

3. Supervise design and preparation of construction specifications and plans for storage facilities, arranging for and ensuring coordination as required among departmental offices.

4. Be responsible for, or assist in, cooperative relationships with other governmental agencies concerned, for example, about environmental or public health aspects of storage.

5. Ensure proper maintenance of facilities after construction, checking, for example, the integrity of drainage channels and basins.

6. Supervise instruction of maintenance workers in environmentally safe handling of salt and other deicing chemicals during delivery, placing in storage, loading, and cleaning up after storms.

7. Perform occasional on-the-spot inspections during winter operations to observe actual handling practices and take steps to improve sub-standard practices.

8. Design and ensure proper use of the department's system for reporting usage of deicing chemicals, for purposes both of divisional management and preventing use of salt in excess of established standards.

9. Review periodic salt use reports, interpret them as necessary to higher authority and other agencies, such as Conservation Commissions and public health officers; when indicated by abnormal reports, take corrective actions to improve storage and handling practices.

10. Schedule annual ordering and deliveries of salt, in relation to capacity of site(s), so as to minimize transfers, spillage, temporary unprotected storage, and similar operations which increase the probabilities of dissolved salt percolating into groundwater.

SUPERVISORY TRAINING

Supervising maintenance engineers are presumed to be mid-career officials, with time to participate only in occasional in-service training courses. Such courses, perhaps a few days in length, should include at least three kinds of teaching techniques: formal instruction, problem-solving exercises, and field observation.

Formal instruction should include consideration of aspects of two basic areas, special engineering topics and environmental protection requirements and procedures. The special engineering topics should include groundwater hydrology; environmental aspects of planning, design, and construction of storage facilities and maintenance areas; and winter operations where salt and other chemicals are used. Environmental quality topics would vary from state to state, but generally include discussions of federal and state environmental laws, implementing requirements prescribed by the Federal Highway Administration and the state highway agency, and finally specific procedures for complying with those requirements, for example, holding public hearings, developing possible environmental impact statements, developing programs for minimizing chemical usage, and meeting regular reporting requirements.

Formal instruction should always be accompanied by a variety of problem-solving exercises which are tailored to the topics and manner of presentation. For example, trainees might be asked to select and evaluate groundwater hydrological data, to identify and rank possible storage sites for a hypothetical highway district, to draft portions of an environmental impact statement required by a state, or to develop operations procedures that will minimize the use of chemicals.

Formal instruction and problem-solving exercises should be complemented by opportunities for observation in the field. Trainees might visit and inspect examples of good storage facilities, observe or even assist in the instruction of maintenance workers prior to the winter season, observe a public or interdepartmental hearing on proposed storage sites.

PART TWO: STORAGE FACILITIES

CHAPTER II

SITE SELECTION

The selection of sites for storage of deicing chemicals has traditionally been governed by selection of road maintenance sites. These, in turn, have often been located on scraps of land left over when the road was built and, for the most part, little consideration has been given to the long-term environmental impact of chemical storage on these sites. In this section are outlined a basic siting methodology, operational requirements and environmental resources to be considered, sources of information needed before sites can be evaluated properly, and guidelines for assessing relative vulnerabilities of sites to pollution.

BASIC SITING METHODOLOGY

The placement of storage piles of deicing chemicals is largely determined by operational requirements discussed later. This is a necessary priority but can lead to locations that are not optimum from an environmental viewpoint. As a result, the storage strategy must rely basically on exclusion of the chemicals from the environment by careful storage building design, careful salt handling procedures, and effective housekeeping in the storage yard vicinity. Environmental siting parameters are, therefore, focused primarily on identifying and describing the relative vulnerability of hydrological, biological and historic/aesthetic resources in candidate storage areas.

In practice, the siting elements function in a decision path shown schematically in Figure 1. Several candidate sites are usually selected

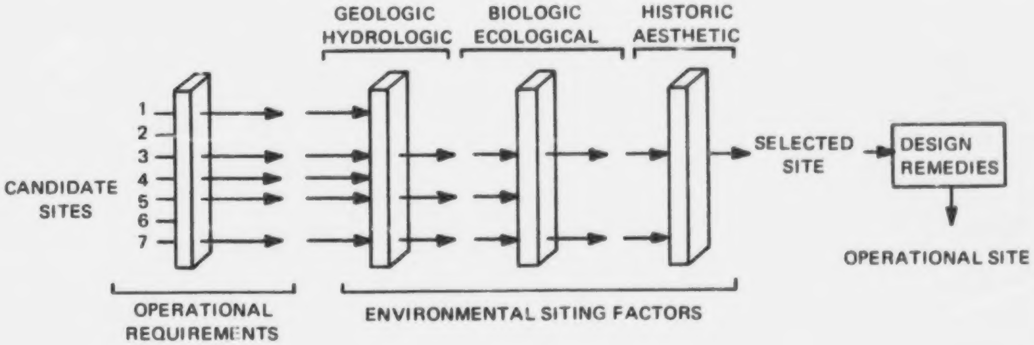

GEOLOGIC
HYDROLOGIC
BIOLOGIC
ECOLOGICAL
HISTORIC
AESTHETIC
1
2
3
4
5
6
7
CANDIDATE SITES
SELECTED SITE
DESIGN REMEDIES
OPERATIONAL SITE
OPERATIONAL REQUIREMENTS
ENVIRONMENTAL SITING FACTORS

Figure 1 Site selection process

on the basis of operational requirements. Expert opinion is obtained from specialists who are competent to evaluate environmental siting factors, which will be discussed in detail subsequently. A site is then selected for "compatibility" with all of the competing requirements. As a final step, design specifications are derived to eliminate or minimize small, residual environmental problems.

OPERATIONAL REQUIREMENTS

The operational requirements for storage and handling of deicing chemicals are governed by snow and ice control policies and user techniques. (For techniques, see Manual for Deicing Chemical Application Practices, EPA-670/2-74-0-045.)[2] Briefly, some of the general requirements are summarized as follows.

- A supply of deicing chemicals should be stored close to the center of the road section in which it is to be used, thereby minimizing the transportation distance between storage and usage.
- Storage should be within or closely adjacent to the right-of-way of a major artery of the road section so that the radius of storage is confined within the radius of maximum usage.
- Adjacent storage locations should be close enough to permit spreader trucks, when properly loaded and operating at normal spreading rates, to reach the boundary of the next road maintenance section and to return before 90% of the chemical or abrasives load has been exhausted.
- The storage site should have sufficient area for structures capable of storing at least one-half (and preferably all) of the seasonal requirements for chemicals and treated abrasives, for one or more loading docks, and for unimpeded access when materials are placed in storage and removed during winter storms.
- Location of the site on a rail siding is highly desirable and strongly advised particularly when large quantities of salt and calcium chloride are to be stored. Shipment in covered hopper gondolas directly from the salt mine or from the supplier's storage minimizes transportation and handling costs, assures quality of the chemical, prevents absorption of moisture, and minimizes unnecessary losses into the environment.

ENVIRONMENTAL RESOURCES TO BE CONSIDERED

Good quality information on geology and soils is the fundamental input needed for the assessment of ground and surface water hydrology. Biologic resources may include but not be limited to nesting or spawing grounds, unique or endangered species and significant ecologic zones such as coastal estuaries, lagoons, or interior wetlands. Historic and aesthetic resources include buildings and/or sites identified by competent authorities as having historical significance; this applies to areas of archeological interest as well as to recreational parks and scenic areas.

The following discussion is intended to provide generally useful background information on the basic environmental siting parameters.

Hydrologic Resources

Groundwater and surface water are closely related in hydrologic terms since, for example, stream water may infiltrate a stream bed and join the groundwater system only later to reappear downstream as recharge to the surface water. Hence, while the two resources are frequently considered apart from one another, they are in fact a part of one continuous water exchange known as the hydrologic cycle. Therefore, contamination introduced to one part of the cycle can lead to contamination of another part.

Groundwater-

Groundwater reservoirs or aquifers, as they are commonly referred to, are as varied in character, hydraulic behavior, extent, and vulnerability to pollution as the geologic terrains that contain them. Groundwater may occur in unconsolidated sand and gravel, fractures in limestone or other consolidated rocks, the pore spaces of a sandstone, or the void spaces in volcanic rocks. The aquifers may be under confining pressure (artesian conditions) or in equilibrium with atmospheric pressure (water table conditions). The aquifers may vary in extent from localized sources capable of a few thousand gallons a day to sources as large as the Ogallala Aquifer, which is about 800 mi (1300 km) long and 300 mi (480 km) wide, including a surface area of 35,000 mi^2 (91,000 km^2) in South Dakota, Wyoming, Kansas, Nebraska, Colorado, Oklahoma, Texas, and New Mexico.

Several typical geologic settings are described below in order to establish their basic characteristics, a necessary prerequisite in evaluation of their vulnerability.

Alluvial valleys -Alluvial valleys such as the one represented schematically in Figure 2 contain unconsolidated sediments (alluvium is gravel, sand, or silt) i thicknesses varying anywhere from less than 10 ft (3 m) to hundreds of feet. Aquifers may be present at very shallow depths and can be of major significance. An example whould be the gravel aquifer serving Schenectady and Rotterdam, New York. The top of the aquifer is about 20 ft (6 m) beneath ground surface and is located in the alluvial valley of the Mohawk River. The aquifer produces about 25 million gal. (95 million l) a day of potable water.

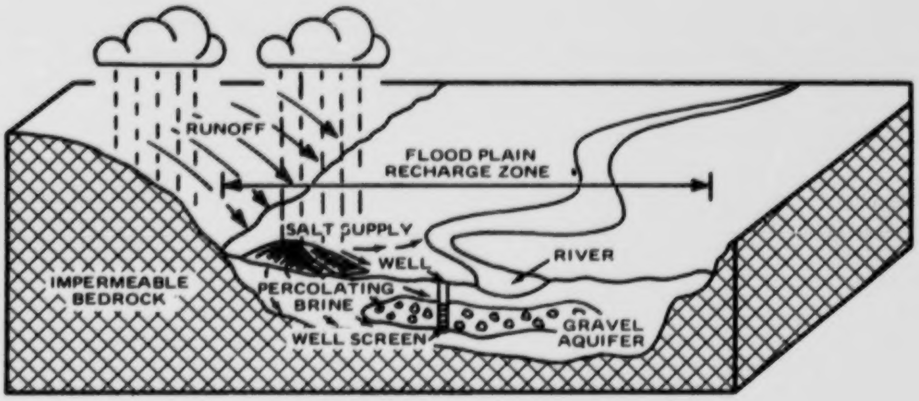


Figure 2 Schematic drawing of an unprotected salt pile leaching into aquifiers beneath alluvial valley

Aquifers of this kind are vulnerable to pollution from a variety of sources including sand and gravel excavation, spills of toxic substances on the surface above them, and degraded surface waters which may be in hydraulic contact with the aquifer. These pollution sources are most critical when they exist or occur within an area influenced by pumping (a recharge zone as indicated on the figure) of large amounts of water from such an aquifer since the sediments overlying the aquifers are usually quite permeable, that is, they are capable of transmitting very large amounts of water to the aquifer. The recharge areas can be identified by standard groundwater hydrologic methods. Protection of these recharge areas is extremely important since it may not be economically practical or even technologically feasible to purify an aquifer once it has been polluted.

Limestone (carbonate) terrains -This geologic terrain, such as is found in Central Pennsylvania (and in many other places), is typified by limestone bedrock with an overlying soil zone of highly variable thickness and composition. Groundwater occurs principally in vertical fracture zones in the bedrock, and, therefore, groundwater flow has highly directional properties unlike that in the alluvial aquifers. For example, a spring at Bellfonte, Pennsylvania produces about 11 million gal. (42 million l) of water a day from a major fracture zone, many miles in linear extent, in the limestone. Generally speaking, contaminants can be transmitted more rapidly in a limestone aquifer than in an alluvial aquifer.

Figure 3 shows an unprotected stock pile being leached by precipitation, with subsequent percolation of the leachate into the groundwater system, and resulting contamination of a water well.

Consolidated porous rock terrains -

A large volume of groundwater is contained in rock units, some of which are deeply buried. These rocks contain interconnected pore volumes capable of holding and transmitting water. The Dakota sandstone in North and South Dakota is such a unit. Aquifers of this type are least vulnerable to pollution from a source such as a salt stock pile. Since withdrawal areas may be very distant from the recharge areas, the pollution problem is potentially less severe.

Surface Water -

The situation with regard to pollution of surface waters is basically less complex than that of groundwater. Surface waters are more accessible to pollution but for obvious reasons are also more amenable to remedies. From an environmental viewpoint, once again emphasis should be placed on exclusion of the salt from the environment, including surface water. Runoff from a salt storage pile should not be allowed to flow into ponds, streams, lakes, or other surface water bodies; this can be accomplished by the proper storage shed and working area design, handling techniques, and housekeeping practices in the storage yard.

Biologic and Ecologic Resources

Biological and ecological resources are enormous in diversity and may be defined as broadly or narrowly as one wishes. Any or all species may be affected by the presence of salt in the environment depending only on the amount and concentration and on the salt tolerance of the species. Basically, the principal of exclusion should once again be utilized to protect these biotic elements of our environment from the effects of salt. Proper storage building design, salt handling techniques, and storage yard housekeeping practices are the best answers to the problem.

Historical/Aesthetic Resources

These siting criteria are perhaps the most difficult to satisfy since they are not simply remedied by good engineering design. In practice the best course is to inventory candidate sites for their proximity and exposure to such areas. Only rarely will all candidate sites be undesirable in this respect; however, failure to address this question may lead to delay in gaining final site approval.

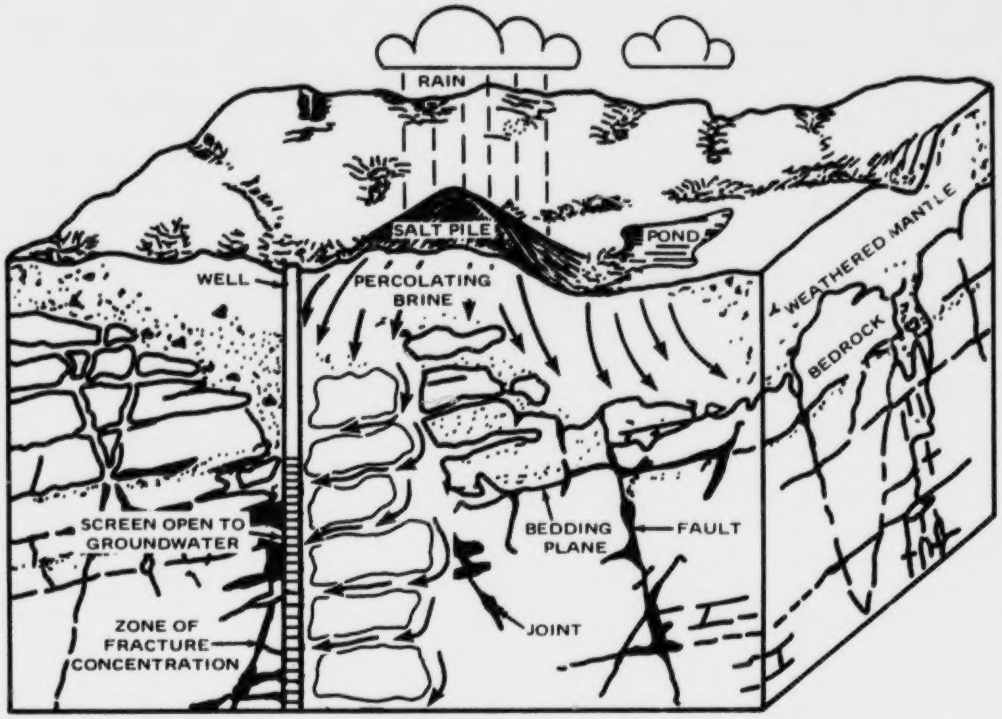

RAIN
SALT PILE
POND
WELL
PERCOLATING BRINE
WEATHERED MANTLE
BEDROCK
SCREEN OPEN TO GROUNDWATER
BEDDING PLANE
FAULT
JOINT
ZONE OF FRACTURE CONCENTRATION

Figure 3 Schematic drawing of an unprotected salt pile leaching into a limestone aquifer

HOW TO OBTAIN NECESSARY INFORMATION

Information required to evaluate the hydrologic, biologic, and historical/aesthetic parameters discussed above can be derived from a number of sources, which are too diffuse in nature and large in number to identify in complete detail. Those basic sources are mentioned here which will lead the inquirer to additional titles and/or experts.

Hydrologic Resources

The largest single repository of information on groundwater in the United States is the Water Resources Division of the U.S. Geological Survey, which conducts investigations, surveys, and research on the occurrence, quality, quantity distribution, utilization, movement, and availability of the Nation's surface- and groundwater resource.

The field organization of the Division is comprised of four regional offices--Northeastern, Southeastern, Central, and Western--each headed by a Regional Hydrologist. Each region consists of several States, and each Regional Hydrologist, with line authority from the Chief Hydrologist, directs water resources programs in his region. The District offices, each headed by a District Chief, generally are located in State capitals with jurisdictional boundaries corresponding to State boundaries.

A series of pamphlets entitled "Water Resources Investigations in (name of particular State)" is a project of the Water Resources Division to inform the public about its current programs in the 50 States and Puerto Rico. Pamphlets for all States are available free upon request to the U.S. Geological Survey, Washington, D.C. 20244. Pamphlets for specific States are available from the appropriate District office listed in a pamphlet entitled "Guide to Regional and District Offices of the Water Resources Division U.S. Geological Survey" which is available from the Director, U.S. Geological Survey Washington, D.C. 20242.

The Guide shows the four geographic areas that make up the regions of jurisdiction of the Regional Hydrologists. Locations, telephone numbers, and office hours for the Regional offices and the District offices are also given.

Basic information on the geology of areas in the United States can be identified by reference to the following documents:

"Publications of the Geological Survey 1879-1961"
"Publications of the Geological Survey 1962-1970"
"Publications of the Geological Survey [year-to-year]"
"New Publications of the Geological Survey [Month-Year]"

These sources will provide access to a vast amount of information. Additional sources include the reports and studies of the State Geological Surveys usually located in the capital cities. Universities also represent a significant resource--particularly the Departments of Geology and Geophysics for groundwater-related issues and the Department of Civil Engineering for surface-water problems.

Finally, in local areas various earth science and engineering consulting companies maintain staffs of experts and usually have highly pertinent local information and experience.

Biological and Ecological Resources

A variety of information sources on the biology and ecology of various regions is available. Clearly, however, the likelihood is small that a highly specific study of the biological and ecological content of an area will be available for each candidate site. Therefore, it will be necessary to obtain qualified assistance in conducting a reconnaissance study of the candidate sites. This assistance may be available from a neighboring university's Biology and Botany department, state/Federal agency, consulting firm, local horticultural group and/or Conservation Commission, State Fish and Game Commission, the National and/or State Audubon Societies.

For example, the Soil Conservation Service provides in their soil series reports for an area, maps of the different soil series for the area with corresponding descriptions of their producing capability and suitability for supporting various vegetation and wildlife. In general, adequate information is available from the sample sources suggested above to meet the needs of the storage facility site selector.

Historical Aesthetic Resources

Local knowledge of historic sites is usually readily available from local historical commissions and societies. Federally designated historic sites are tabulated in the *National Register of Historic Places.* Aesthetic resources are basically those associated with existing or planned park and/or recreational areas. (This is not to say that areas outside this definition have no aesthetic value or merit.) The most useful sources of information on such areas are local Conservation Commissions, Planning Boards, Park Commissions (both State and local), as well as Regional Planning Agencies. Additional information resources include but are not limited to the various State Audubon Societies and other groups who are active in studying the environment.

SITE VULNERABILITY ANALYSIS

At this point a general methodology has been established for salt storage facility siting, and several important environmental variables have been identified, together with sources of information related to them. The responsible official must now, with access to technical advisors, identify that site which is operationally and environmentally best suited to use as a salt storage facility.

It is fair to say that salt effects on water supply have loomed largest in terms of the environmental impact of salt storage and, most particularly, salt usage. Biological and botanical responses to salt have largely involved salt usage, although inadequate storage practice can lead to similar problems. Historical and aesthetic qualities are most related in terms of impact by the storage of salt and not to salt usage. As a result, the following priority areas of environmental concern in terms of salt storage are suggested.

- Protection of water supplies--groundwater and surface water and
- Preservation of the historical or aesthetic character of a site.

Clearly, the first of these is preeminently important in terms of environmental protection. Sites should be excluded from consideration if:

- They are within or adjacent to a municipal groundwater well field or an area of residential development which is dependent on well water either on a single house basis or from a private water company or

- They are in close proximity to surface water bodies, particularly small ones and those used for public water supply.

One additional operational problem requires special mention. Salt trucks are generally hot-water washed for maintenance purposes. All of the good housekeeping, storage shed design, and handling expertise is wasted if the truck wash area runoff is either:

- Released untreated to the area's surface drainage network or is

- Directed to a sump and allowed to percolate into the groundwater system.

Although the decision maker must realize that salt usage in the highway environment is perhaps the more critical problem to be addressed, the storage facilities represent a potentially very large, concentrated point source of pollution and must be treated as such. The selected site should be acceptable from the viewpoint of operations and be the least environmentally problematic of the sites examined. Any remaining environmental problems should be minimized through appropriate design of structures and appurtenances on the site.

CHAPTER III

FOUNDATIONS AND WORKING AREA DESIGN

The foundation of salt storage buildings, the paving of the floor within the building, and the attention given to the drainage and paving of the working area adjacent to salt storage buildings are as important for environmental protection as the decision to place salt under cover. In this section are outlined basic designs for foundations of salt storage buildings, and a loading dock, pavements within and adjacent to the buildings, and factors to be addressed when designing the area drainage.

PREREQUISITES TO FOUNDATION DESIGN

Foundation design for salt storage buildings is not complex. In some respects these buildings are similar to barns, which have been constructed for centuries in all parts of the world without the benefit of either structural or foundation analysis. Nevertheless, there are some unique factors which should be taken into account.

The foundation designer will require data and information as follows:

- Topography (existing and proposed).
- Type of soil and subsurface conditions.
- Climatology.
- Type and layout of structure, including dead and live loads.
- Proposed salt load.
- Live load due to equipment.
- Applicable building codes.
- Operating and other information.
- Aesthetics.

Factors to be considered within each of these categories are discussed below.

Topography

The elevation of the interior floor slab should be sufficiently above the exterior yard area to prevent inflow of rainwater. If the foundation walls extend above grade and it is desirable to use exterior earth pressure to resist the interior salt load, it may be necessary to site the structure by cutting into a hillside. Final grading around the shed should be designed to slope away for drainage purposes.

Type of Soil and Subsurface Conditions

Common good practice rules for foundation design apply here. In areas with which the design engineer is familiar, a few auger borings should suffice. But if compressible substrata are possible or if ledge may be encountered, borings and soil tests should be made in sufficient quantity to identify clearly the subsurface conditions. If test pits are dug in lieu of borings, they should either be located outside of the floor slab area or the material should be compacted when it is replaced.

Climatology

The principal items are the depth of frost penetration in the area and the annual snow depth.

Type and Layout of Structure, Including Dead and Live Loads

The foundation designer will need to know the maximum loads to be transmitted to the foundation, the points at which they are transmitted, and the type of fasteners (e.g., anchor bolts). Thrust, shear, and bending moment loads should be provided. On large sheds, wind loadings should be checked to determine possible uplift loads and snow loadings should be determined. If the foundation extends above grade, i.e., forms part of the wall, the dimensions for doorways and locations for electrical conduits or other piping should be provided.

Proposed Salt Load

In general, the salt load on the floor slab will be less than floor loads from vehicles. However, the lateral loads on the walls are unique to bin design, and the maximum height of the salt against the wall must be known. If the shed is to be compartmented, either for storage of both sodium and calcium chloride or to provide a vehicle parking space, the desired architectural details will be required.

Live Load Due to Equipment

The salt delivery trucks, the spreader trucks, and the loader must all be considered.

Applicable Building Codes

These will provide such information as minimum concrete cover over reinforcing bars, minimum foundation depths, electrical codes, and earthquake criteria. Local (municipal) codes may contain special provisions, and if the structure must comply with such regulations it is generally advisable to use a local designer or consultant who is familiar with the regulations.

Operating and Other Information

The foundation designer may be asked to design a loading dock in the yard area, and the location, height, and dimensions of the dock should be provided (see "Working Area Design"). It is also possible that a buffer wall is to be constructed inside of the shed walls to keep the salt away from the walls, either to prevent corrosion or to prevent the salt from bearing on the walls. Consideration should also be given to loader operations in the shed; protrusions or dead corners which cannot be reached should be avoided. If the foundation extends above the floor slab grade, it should be protected from the loading bucket by a buffer strip, extra concrete thickness, and battered sides.

Aesthetics

If the foundation is visible, it may be desirable to provide some architectural treatment to suit the locale. This would probably only involve finishing of exposed concrete surfaces.

FOUNDATION DESIGN CONSIDERATIONS

Specific design criteria for walls and foundations can be obtained from standard texts on foundations. The salt itself has a bulk density of 80 lb per ft^3 (1280 kg per m^3) and an angle of repose of 32 degrees from horizontal. In the absence of specific structural, subsurface, and other data, it is not feasible to present any specific designs here; however, some general considerations are presented through an examination of the principal variables involved.

The basic elements of a storage shed are shown in Figure 4. The wall is clearly the unique part of the structure since it must resist the outward thrust of the salt load. This will in turn affect the foundation design, and, in fact, the wall and foundation can be an integral structural unit--at least up to the highest point of salt stockpiling. There are two general approaches to the wall design--continuous and buttress.

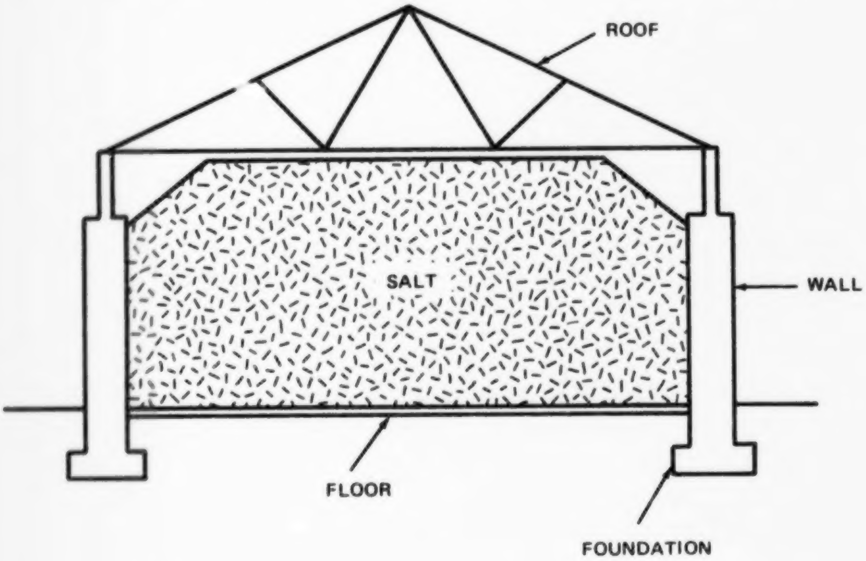


Figure 4 Basic elements of salt storage shed

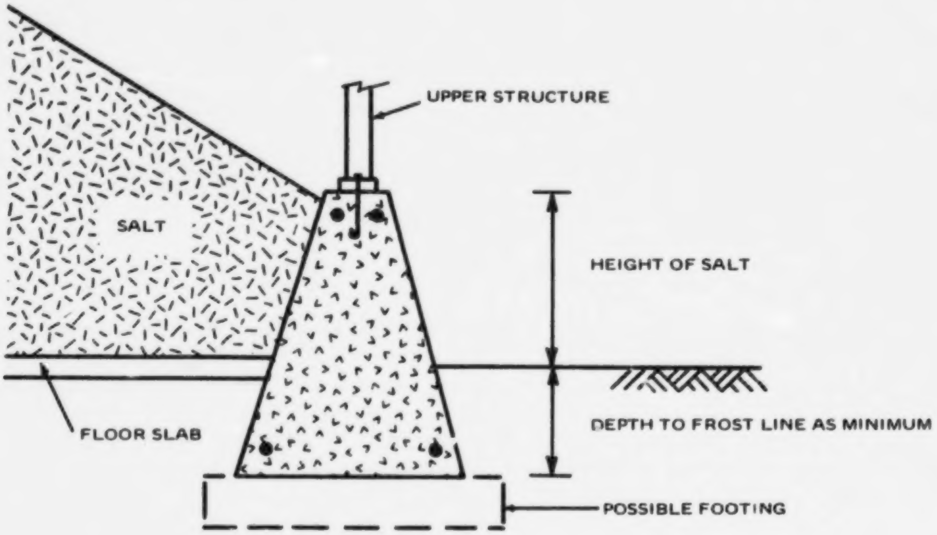

UPPER STRUCTURE
SALT
HEIGHT OF SALT
DEPTH TO FROST LINE AS MINIMUM
FLOOR SLAB
POSSIBLE FOOTING

Figure 5 Continuous wall foundation (gravity)

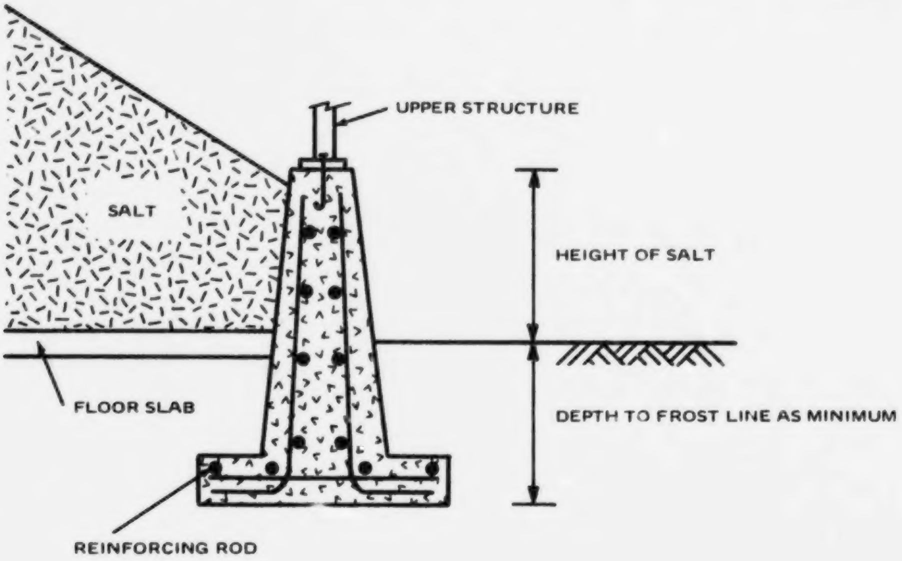

UPPER STRUCTURE
SALT
HEIGHT OF SALT
FLOOR SLAB
DEPTH TO FROST LINE AS MINIMUM
REINFORCING ROD

Figure 6 Continuous wall foundation ("T" wall)

Continuous Wall

In the continuous design, the wall-foundation is similar to an earth-retaining wall, and the remaining structure rests on the top of the wall in a fashion similar to the way any ordinary structure rests on a continuous footing. The continuous wall-foundation may, therefore, be designed as a gravity or "T" wall, as shown in Figures 5 and 6. The advantage of the gravity wall is that it needs little reinforcing steel, but conversely it uses more concrete. For support of relatively low piles of salt (e.g. 3 ft-4 ft or 0.9 m-1.2 m), the gravity wall-foundation is often used.

The "T" wall utilizes the weight of soil on the loaded side to resist the overturning moment. It is much more economical with respect to concrete requirements, but uses more reinforcing steel which must be accurately placed in the forms. Since salt is liable to corrode the reinforcing steel, the "T" wall should be protected either by an impermeable coating (such as linseed oil or epoxy) on the interior and/or use of galvanized reinforcing.

It is important to design the portion of the wall-foundation that is above grade so as to exclude rain leaks at the building wall sill. The top of the wall-foundation should be sloped to the outside, and/or a flashing should be placed along the bottom of the building wall. The interior of the wall-foundation should have a slight batter to keep the bucket of the loader from scraping the wall. These details are shown in Figure 7.

The continuous wall-foundation will require expansion/contraction joints at about 30-ft (9-m) intervals. In order to protect any continuous reinforcing steel at such locations, a waterstop should be installed on the salt (interior) side of the joint.

Buttress Wall

The alternative to the continuous wall-foundation is the "buttress" design, which includes several variations. The basic concept is shown in Figures 8 and 9. The design principle is that the salt load against the side wall is transmitted to buttresses at discrete points along the wall. The buttress may also serve as a structural column of the building. The buttress may consist of a strut or it may be a concrete buttress as indicated in Figure 9.

Although the buttress design should be more economical than the continuous wall design with respect to materials, it can also add design and construction complexity since the wall must be designed to resist outward buckling forces. An exception would be a simple building using steel columns without buttress struts, such as shown in Figure 10. This design may incorporate cables across the roof and under the floor slab to resist outward forces on the columns.

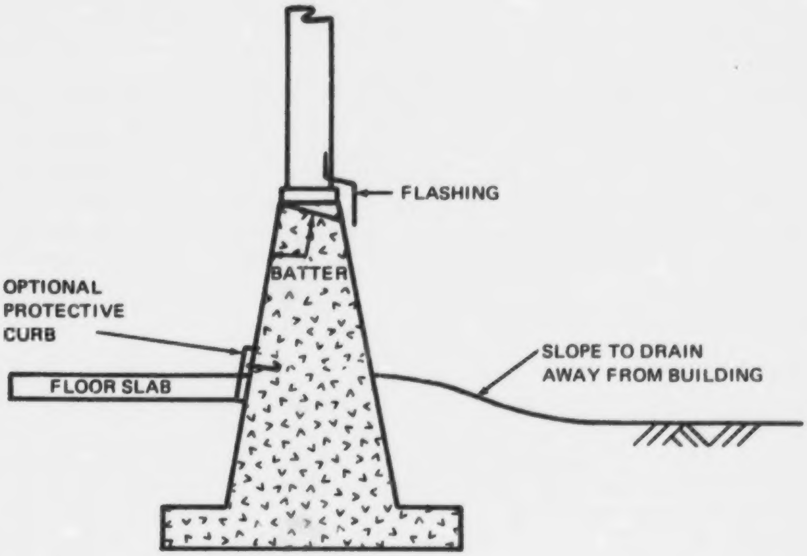


Figure 7 Wall-foundation details

For some salt storage sheds, a separate wall or bulkhead is constructed inside of the exterior wall to hold the salt, as indicated in Figure 11. The bulkheads may be independent units as suggested by the continuous wall in Figure 11(top), or they may be tied to the building columns as shown in Figure 11 (bottom). Interior bulkheads serve to keep the salt away from the walls, thus avoiding corrosion problems, and they permit the use of standard pre-fab buildings not designed for bulk storage. In an arch-support structure (Figure 11,top), they also serve to keep the salt away from the low-roofed section of the shed that cannot be entered by the loading equipment.

Material

Reinforced concrete will likely be the principal construction material. Highway engineers are aware of the spalling and corrosion problems that heavy road salting has caused on concrete pavements and bridge decks, and the use of concrete foundations for salt storage sheds may seem to be inviting early failure. However, highway slabs are exposed to infiltration of salt solution due to rains and alternate cycles of freezing and thawing. Since the interior of the salt shed is to remain dry, it should not be exposed to the same corrosive cycle. Nevertheless, it is recommended that air entrained concrete or a dense (impermeable) mix be used to avoid spalling. Reinforcing steel should have a slightly thicker

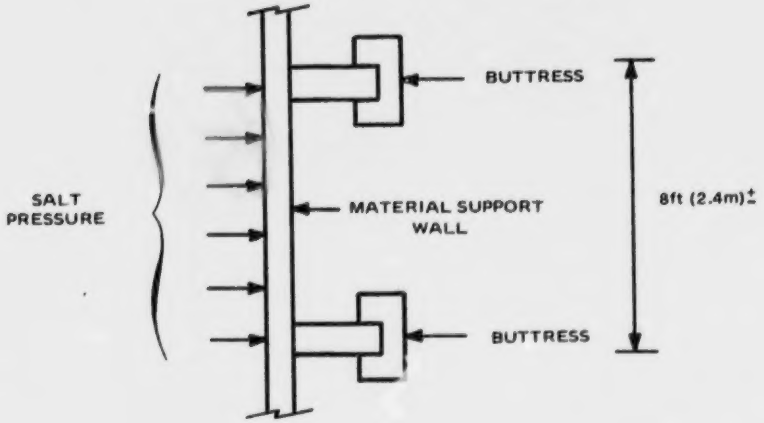

BUTTRESS
SALT PRESSURE
MATERIAL SUPPORT WALL
8ft (2.4m)±
BUTTRESS

Figure 8 Plan view of buttressed wall and foundation design

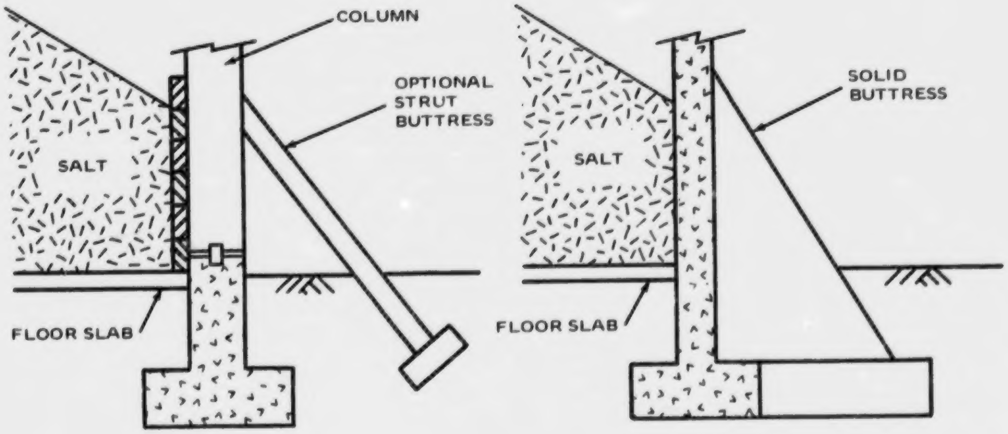

COLUMN
OPTIONAL STRUT BUTTRESS
SALT
FLOOR SLAB
SOLID BUTTRESS
SALT
FLOOR SLAB

Figure 9 Typical sections of strut (on left) and solid (on right) buttresses

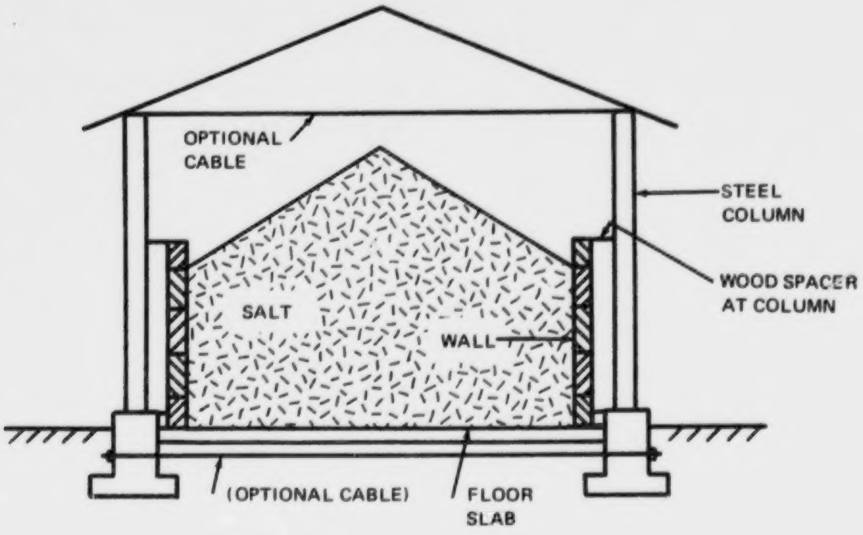


Figure 10 Section of shed with steel columns and interior buttress wall

minimum cover, and it should be protected at joints. The inner wall should be painted with an impervious material (linseed oil or epoxy) and touched-up annually.

Doorways and Corners

The doorway and corners of the shed may require special foundation design. From the operational viewpoint, the end of the shed should be completely open to allow trucks and loaders to enter easily and to avoid dead corners. However, if the entrance is to have doors, and if they are to be opened horizontally by sliding, some space must be provided for them to occupy when opened. This can either be along the end walls of the building or on an extension trestle. If the latter cannot be cantilevered from the building, exterior footings may be required.

If the door height or the lower chord of the interior roof trusses is not high enough for a delivery truck to enter and dump the salt in the shed, the salt will have to be dumped outside and pushed or carried inside by a loader. If this is the case, a paved entrance area should be provided. The sides of this area could have training walls as shown in Figure 12 to facilitate pushing the salt into the shed.

A large entrance doorway will present special structural requirements on the building, since in effect an entire wall is lost. As a result,

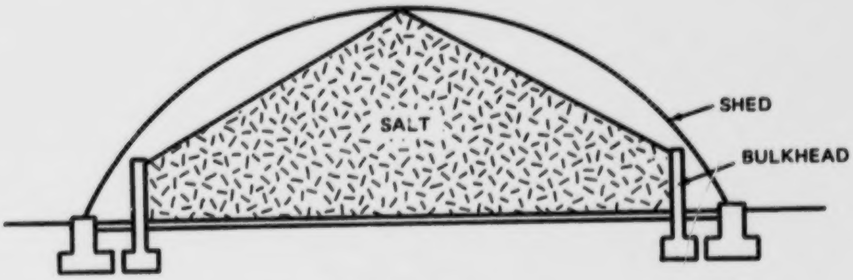

SHED
SALT
BULKHEAD

Figure 11a

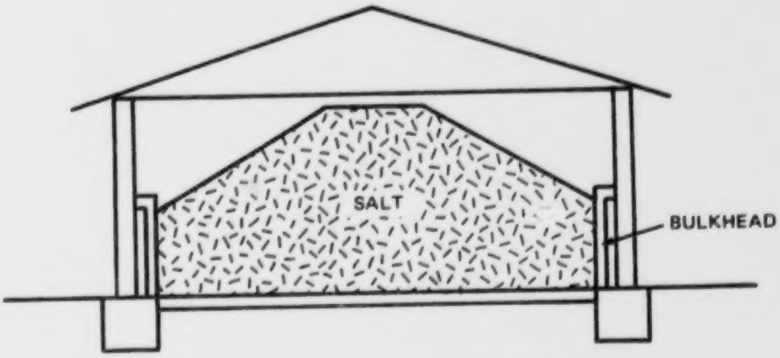

SALT
BULKHEAD

Figure 11b

Figure 11 Interior bulkhead walls

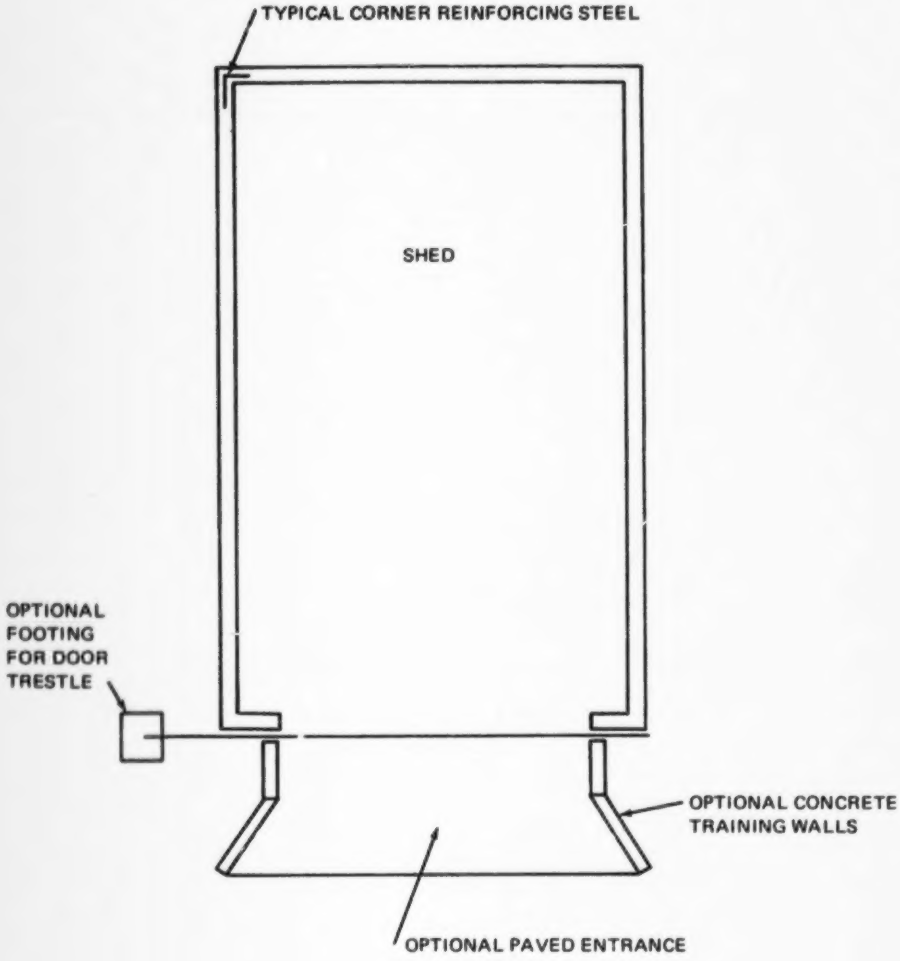

TYPICAL CORNER REINFORCING STEEL
SHED
OPTIONAL FOOTING FOR DOOR TRESTLE
OPTIONAL CONCRETE TRAINING WALLS
OPTIONAL PAVED ENTRANCE

Figure 12 Plan view showing optional foundation details

the stub walls at the entrance will have to carry unusual loads for diagonal stiffness and the door trestle. As a result, the doorway foundation area may be subject to unusual loads and must be designed accordingly.

Paving

The floor slab inside the building should be impermeable to prevent possible contamination of the ground by the salt. The usual practice is to use a bituminous concrete flexible pavement similar to what would be used for parking areas or service roads. Typically this would be a 2.5-in. (6-cm) surface (1.75-in. or 3.2-cm wearing course over a 1.75-in. or 3.2-cm leveling course), laid over a 6-in. (15-cm) compacted gravel base. If the native soil is clay-like, an additional 12-in. (27-cm) sand or gravel sub-base should be installed. The floor should pitch to drain out of the entrance doorway using a slope of about 0.5°. An emulsified tar coating should be applied over the bituminous concrete to protect it from any gas or oil spills from operating equipment.

WORKING AREA DESIGN

Drainage Considerations

Creation of some salt brine at a salt storage facility is inevitable, particularly during and after storms. Although diversion and collection of the brine is possible through proper site design, ultimate disposal of brine is itself environmentally problematic, and no completely satisfactory method has been devised.

In 1972, a study of control of salt brine runoff was conducted by the Minnesota Highway Department[3] and illustrates the problems in disposing of brine runoff. The only effective means of control was found to be collection of brine in a completely sealed basin or pond. Evaporation was not feasible as a means of disposal because of the large surface area required and the need to limit access to and the unappealing appearance of such a brine pond. Disposal by dumping and hauling was costly and selection of an appropriate disposal site was found to be difficult at best. Pumping of brine back into a sand pile was only feasible if the volume of brine was small or if a sand pile was available. Because most of the annual precipitation occurs during the summer months, pumping of brine into trucks loaded for snow and ice control was seen as a possible, but unlikely, means of disposal. As a result of these findings, the study concluded that collection facilities are a last resort and that "time, effort, and money, in most cases, can be better spent on avoiding or minimizing the formation of salt brine".

In areas in and around groundwater well fields or surface fresh water reservoirs, all brine runoff must be contained in a lined catchment basin and be disposed of in a less vulnerable area.

One salt runoff storage basin developed by the Pennsylvania Department of Highways is shown in Figure 13. Several of these basins may be placed

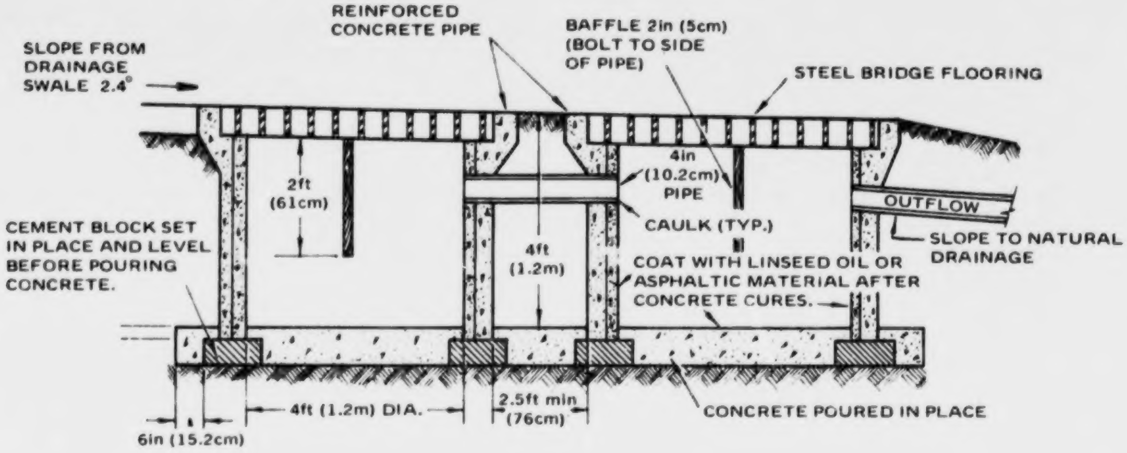

REINFORCED CONCRETE PIPE
BAFFLE 2in (5cm) (BOLT TO SIDE OF PIPE)
SLOPE FROM DRAINAGE SWALE 2.4°
STEEL BRIDGE FLOORING
2ft (61cm)
4in (10.2cm) PIPE
OUTFLOW
CAULK (TYP.)
SLOPE TO NATURAL DRAINAGE
CEMENT BLOCK SET IN PLACE AND LEVEL BEFORE POURING CONCRETE.
4ft (1.2m)
COAT WITH LINSEED OIL OR ASPHALTIC MATERIAL AFTER CONCRETE CURES.
4ft (1.2m) DIA.
2.5ft min (76cm)
CONCRETE POURED IN PLACE
6in (15.2cm)

Figure 13 Salt brine storage basin
Courtesy of Pennsylvania Department
of Transportation

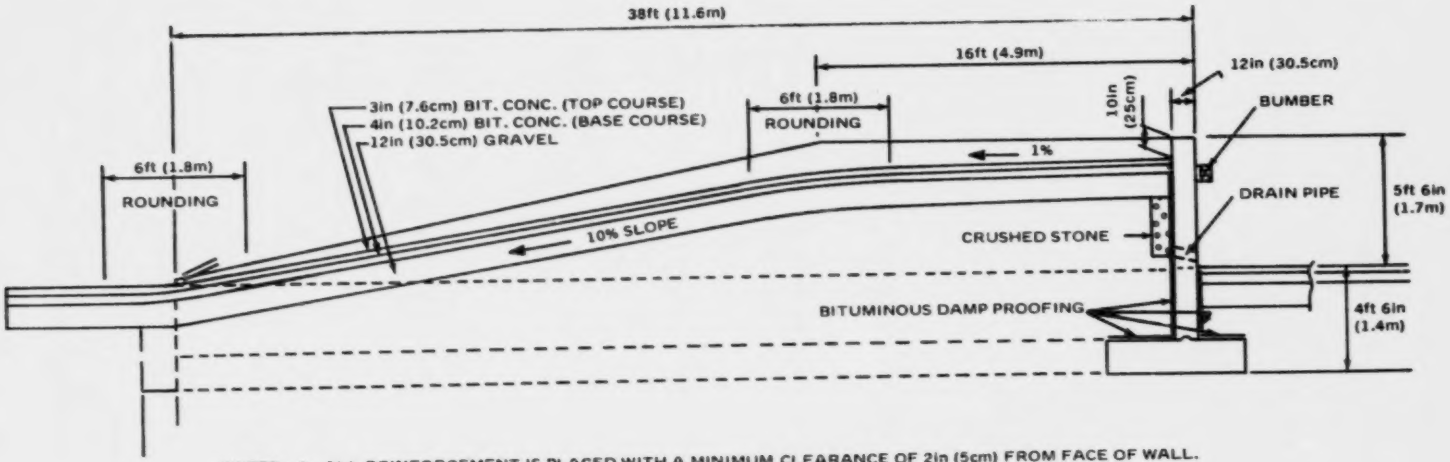
in a series to increase the storage capacity. Ideally, capacity should be sufficient so that there is no overflow, even during periods of heavy precipitation.

Brine from basins such as the one shown is pumped onto sand stockpiles, and crystallized salt and other settled solids are cleaned out during the summer.

In summary, the first priority in brine control should be to eliminate its occurence as much as possible. Proper site selection and storage design and good housekeeping practices will all minimize the formation of salt brine.

Loading Ramps or Docks

The efficiency of the front-end loader, overwhelmingly preferred for salt handling and loading spreader trucks, can be greatly enhanced through incorporation of a loading dock or a loading ramp in the chemical and treated-sand storage area. Often, in the design of a storage area, advantage can be taken of natural terrain to incorporate a loading dock in front of or adjacent to the chemical storage area. The height of this dock can vary anywhere from 2 ft to 6 ft (0.6 m to 1.8 m), thereby reducing by this amount the height to which the operator must lift the front-end loader when placing loads in spreader trucks. A ramp designed by the Massachusetts Turnpike Authority shown in Figure 14 is particularly adapted to storage areas in flat terrain.


38ft (11.6m)
16ft (4.9m)
12in (30.5cm)
BUMBER
10in (25cm)
6ft (1.8m)
ROUNDING
3in (7.6cm) BIT. CONC. (TOP COURSE)
4in (10.2cm) BIT. CONC. (BASE COURSE)
12in (30.5cm) GRAVEL
6ft (1.8m)
ROUNDING
1%
10% SLOPE
DRAIN PIPE
5ft 6in (1.7m)
CRUSHED STONE
BITUMINOUS DAMP PROOFING
4ft 6in (1.4m)

NOTES:
1. ALL REINFORCEMENT IS PLACED WITH A MINIMUM CLEARANCE OF 2in (5cm) FROM FACE OF WALL.
2. ALL EXPOSED CEMENT CONCRETE SURFACES ARE TREATED WITH TWO APPLICATIONS OF LINSEED OIL.
3. BUMPER IS SOUTHERN PINE NO. 1 SR (f=1500) OR DOUGLAS FIR CONSTRUCTION GRADE (f=1500) PRESSURE TREATED WITH 6 LB. RETENTION OF PENTOCHLOROPHENOL. BOLTS ARE COATED WITH BITUMASTIC NO. 50 (KOPPER CO. INC.) OR APPROVED EQUAL AT EXPOSED ENDS AFTER INSTALLATION.
4. REINFORCEMENT IS CONTINUOUS THROUGH WALL CONSTRUCTION JOINTS.

Figure 14 Section of a loading ramp
Courtesy of Massachusetts Turnpike Authority

CHAPTER IV

DESIGN OF STORAGES

In this section are presented functional and environmental requirements for storages and their surroundings, designs of storages that are environmentally sound, designs that are acceptable, and storage practices that must be avoided. Wherever possible, information on cost of storage structures has been included.

ENVIRONMENTAL REQUIREMENTS

The environmental impact of storage and handling of deicing chemicals prior to use on highways is the one major impact that can be controlled most carefully. In the past, poor design of storages and improper handling have been responsible for many of the environmental abuses of deicing chemicals.

The environmental requirements for the design of storages are rules that should never be violated:

- Storages should protect the chemicals from direct rain and blowing snow at all times; they should keep the material dry and out of the weather.
- They should keep the material within the prescribed boundaries of the storage.
- They should not leak chemicals or burst particularly during abnormally rough usage or through accidental mishandling.

FUNCTIONAL REQUIREMENTS

The functional requirements of storages for deicing chemicals are closely interwoven with the operations of the road maintenance district and the techniques used for handling the chemicals.

- Storages should be large enough to hold the maximum amount of chemicals without overflowing. As a rule of thumb, the storage should be capable of holding at least one-half of a season's requirements and preferably all of the seasonal requirement.
- Special handling procedures should not be required to store all of the chemical under cover immediately upon delivery.
- Sufficient vertical clearance should be provided either inside the storage or immediately in front so that delivery trucks can unload easily without damaging the structure.

- Horizontal clearance in the storage and at the entrance should be sufficient to enable front-end loaders to place material within the storage and to remove it during winter storms.

- The storage should be sturdy enough or suitably reinforced at key locations to withstand the normal rough usage that occurs during winter operation.

- Good exterior and interior lighting should be provided for nighttime operations.

ARRANGEMENT WITHIN OPERATIONS AREA

The location of chemical storages in operation areas depends on operational factors (see Manual for Deicing Chemical Application Practices[2]), the site terrain (including drainage), the location of access roads, and a host of other minor factors. Included herewith are descriptions of four classes of operation areas that illustrate important storage design characteristics. These storages include a major distribution center, a district base area, a crew area, and a reload area. Each of these storage areas will be described.

Major Distribution Center

In a typical major distribution center that supplies a large geographical area, chemicals are received by covered hopper rail cars, barges, or ocean vessels. More than 100,000 tons (90,700 t) of chemicals may be stored on a site of this type. Due to the large quantity involved, the material is seldom under permanent shelter. Materials are usually stored under tarpaulins or reinforced plastic film, which are spread on the pile and stitched together along seams with hand-held portable sewing machines. Material is usually removed from the pile by large front-end loaders, is loaded into large dump trailers, and then delivered to customers within about a 50-mi (80-km) radius. Limitations on the quantity of chemicals that may be stored on a site of given size are governed primarily by the requirements for vehicle circulation around the storage areas during the loading and unloading operations.

District Base Area

The district base area typically services an area consisting of 1500 or more lane miles (2400 lane km) of road and has several crew areas and reload areas under its direct responsibility. Typically, the district base area will include repair facilities with up to 12 bays, garaging for as many as 50 pieces of equipment, equipment storage yards, and a chemical storage capability of up to 3000 tons (2700 t). Additionally, there should be provision for storage of treated abrasives (sand or cinders) when these materials are used in the snow and ice control program. One or more ramps are provided for loading trucks with chemicals and/or abrasives. Provision is made in the layout of the base area for vehicle circulation and for the storage of snow that is removed from the working area during periods of winter storms.

Crew Area

The crew area typically services an area with about 100 lane miles (160 lane km) of road. It usually consists of a heated garage with a wash rack, a closed building with up to 1500 tons (1350 t) capacity for chemical storage, and a ramp for loading spreader trucks. Provision may also be made for storage of treated sand or other abrasives.

Reload Area

The reload area is typically located near the dividing line between two crew areas and is used often by both crew areas to provide spreader trucks with chemicals and/or grit for the return trip. Up to 500 tons (450 t) of chemicals are stored in a small covered shed. Electric power is provided at the site for lighting night operations and for maintaining the front-end loader, typically used at these sites, in a state of readiness for operation even in the coldest weather. A ramp is provided for loading spreader trucks.

GOOD PRACTICE IN SALT STORAGE

Many approaches to salt storage were observed during the course of this study. Some of these combine operational features very successfully with environmental requirements and are, therefore, considered to represent good practice in salt storage.

The specific approaches outlined in this discussion were chosen to represent good practice within a range of storage capacities and a sampling of available construction materials and designs. They are shown with the permission of corporations and highway maintenance agencies; in the case of the latter, the specific designs shown are not necessarily representative of all or most current practice within the agency.

Notable Features

The sample storage sheds illustrate some notable features:

1. Any salt storage (shed, overhead hopper, or pile) must be oriented so that truck-loading operations are shielded as much as possible from prevailing winds.

2. Storage sheds with open front faces may be protected by ample roof overhang from intrusion of rain and snow.

3. Complete enclosure of the salt storage with doors is more important for security reasons than for protection from moisture. When the storage area is in or near an inhabited area and access cannot be limited effectively by gates, fences, or other means, doors (with locks) are often essential.

4. Within any salt storage structure, sloped floor drainage and drain pipes are necessary to divert any accumulated water away from the salt pile and out of the structure.

5. In addition to a solid floor within the enclosure, an asphaltic concrete pad is essential in all loading/unloading areas near a storage shed to insure that spilled salt does not dissolve and percolate into the soil and can be scraped up easily for subsequent use.

6. Ample room must be provided for operation of a front-end loader. Any portion of the structure within its reach can be damaged during operations. Various means of reinforcement of vulnerable areas (especially door jambs and corners) are illustrated in the designs shown. (See "Designing for Durability.")

7. Sharply sloping roofs such as those in arch-type and conical structures can be protected by interior retaining rings or timber bulkheads, which keep the salt pile (and loading activities) away from the corners and in some cases bear the salt load.

8. All hardware and metal building elements must be galvanized.

9. When loading and unloading operations are to occur inside the storage, adequate ventilation must be provided.

10. Lighting must be provided inside of storage buildings and in the loading area in front to illuminate nighttime operations.

Wooden Arch Storage Building

The Massachusetts Turnpike Authority utilizes a building with laminated wooden arches as shown in Figure 15. Spanning 60 ft (18 m) and rising to 25 ft (8 m) at the crown, the circular arches are bolted to square foundation posts of reinforced concrete 8 ft (2.4 m) on center. Wood purlins (2-in. by 8-in., 5-cm by 20-cm) span between arches, and the exterior skin is formed by plywood. The end walls, supported by double 2-in. by 8-in. (5-cm by 20-cm) posts, on an 8-in. (20-cm) reinforced concrete curb, are also sheathed with plywood. The whole structure is painted, inside and out. A heavy timber bulkhead protects the end walls and base of the laminated arches on the inside and supports the salt to a height of 5 ft (1.5 m); the tongue-and-groove 3-in. (8-cm) planks are pressure-treated. Cast-iron wheel guards protect the jambs of the front opening from damage by loaders. The bituminous concrete floor paving drains toward the opening. This 60-ft by 80-ft (18-m by 24-m) structure has a design capacity of about 1000 tons (900 t).

The loading ramp (shown in Figure 15) in front of the storage building facilitates loading of salt trucks.

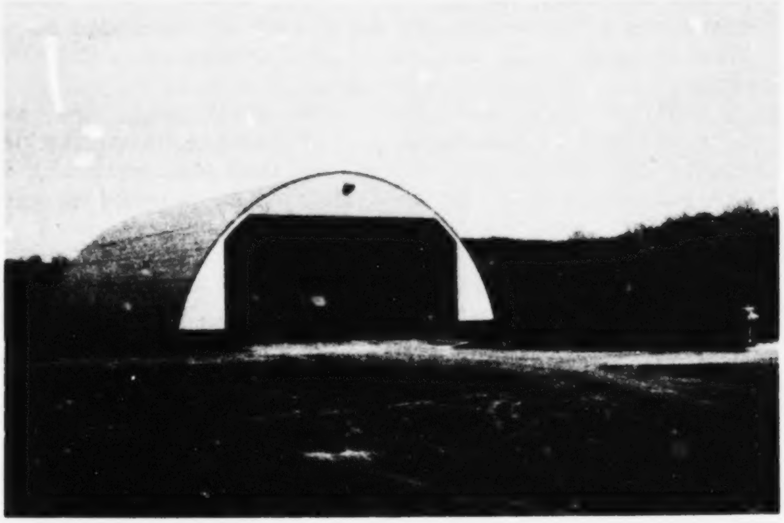


Figure 15 Wooden arch storage building with loading ramp
Courtesy of Massachusetts Turnpike Authority

Wooden Rigid Frame Storage Building

Another design (see Figure 16) developed by the Massachusetts Turnpike Authority utilizes rigid frames of laminated wood spanning 60 ft (18 m). The two-piece laminated frames, spaced every 20 ft (6 m), are bolted together at the top and anchored at the bottom to a continuous reinforced concrete parapet and wall foundation. Double 2-in. by 8-in. (5-cm by 20-cm) posts at the side walls between frame members and 2-in. by 12-in. (5-cm by 30-cm) purlins spanning frames at the roof support the plywood skin. The end walls have a similar reinforced concrete parapet. The whole structure is painted inside and out.

As in the wooden arch structure, a 6-ft (1.8-m) heavy timber bulkhead of pressure-treated, 3-in. (8-cm), tongue-and-groove planks bears the salt load and protects the interior structure on all sides. A similar bulkhead divides the interior space into two storage bays. Cast-iron guards protect the jambs of the almost full-width front opening. The floor surface is bituminous concrete. Measuring 56 ft by 77 ft (17 m by 23 m) inside, this structure has a design capacity of 1500 tons (1400 t) of salt.

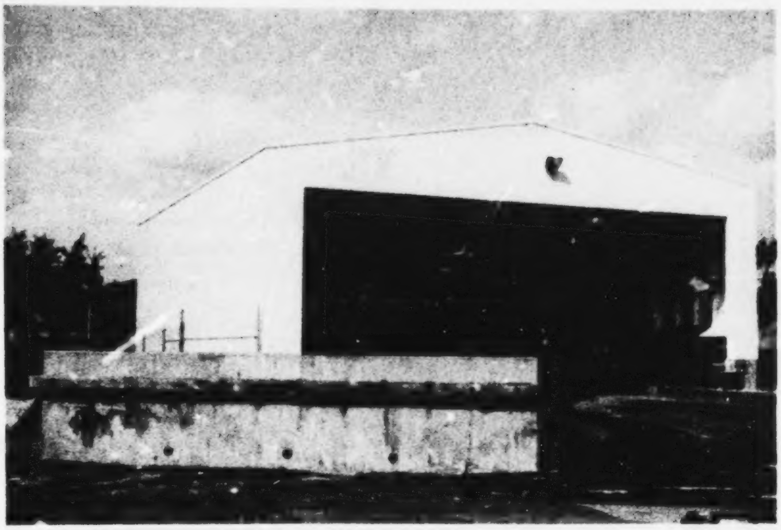


Figure 16 Wooden rigid frame storage building with loading ramp
Courtesy of Massachusetts Turnpike Authority

Dual Storage Building

The California design shown in Figure 17 provides for separate storage of cinders or sand and salt under the same roof. Measuring 50 ft by 100 ft (15 m by 30 m) overall, the structure includes an 80-ft by 50-ft (24-m by 15-m) area for cinder or sand storage with access through the front opening and a 20-ft by 50-ft (6-m by 15-m) salt storage bin across the back of the building with access through a door on the rear side wall. The design capacity is 300 tons (270 t) of salt and 1700 tons (1540 t) of cinders or sand. The basic design could be adapted for all salt storage.

A rigid frame steel structure is metal clad, reinforced to withstand horizontal thrusts from sand, salt, wind and seismic loading conditions. Each frame is tied between base plates through the reinforced 6-in. (15-cm) concrete floor slab, with sway braces in the roof and walls providing additional stability. A 7-ft (2-m) high reinforced concrete perimeter wall inside the rigid steel framing encloses the sides of the shed and separates the front and rear storage areas.

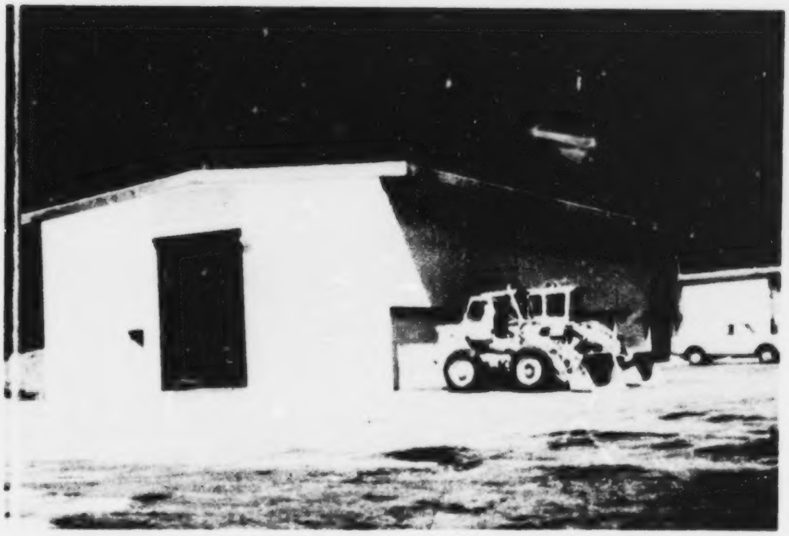


Figure 17 Dual storage building
Courtesy of State of California Department of Transportation

Note: Sand and cinders are stored in the main part of the building (left side of photograph), and salt is stored in the transverse salt bunker at the back of the building (behind the pickup truck).

Both exterior openings are closed by sectional overhead doors. Columns of 6-in. (15-cm) pipe protect door jambs from damage by mechanical loaders. Metal cladding with light steel framing forms the skin of the upper walls and gabled roof. Powered rotary vents at the ridge line, metal louver vents at each end, and continuous vents at the top edge of the metal cladding facilitate ventilation, which is essential because loading of spreaders occurs inside of the structure. Floor slabs are pitched to drain toward the doorways.

This structure is designed in four grades to withstand the snow loading experienced at altitudes up to 3,000 ft (900 m), 4,000 ft (1,200 m), 5,000 ft (1,500 m), and above 5,000 ft. The cost of the shed increases with the snow loading requirements. A new design is being developed with a steel structure resting on top of the reinforced concrete base, raised eaves to 16 ft (5 m), and a flat roof. Construction of this new shed is expected to be more economical.

Concrete and Wood Storage Building

One salt storage building developed by the Maine State Highway Commission is a composite concrete and wood shelter (Figure 18). The bottom 4 ft (1.2 m) of the shed walls are concrete with inside batter of 3 in. per ft (25 cm per m) and outside batter of 1 in. per ft (8.3 cm per m), reinforced at corners and at either side of the doorway, and resting on a continuous concrete foundation. This concrete base prevents rotting of the timber walls by surface water and minimizes damage to the walls above by mechanical loaders. Careful sloping of the floor prevents any accumulation of water in corners.

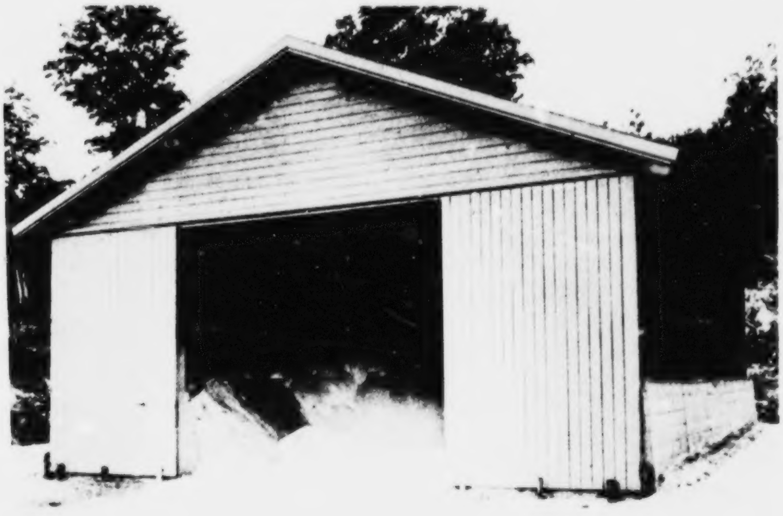


Figure 18 Concrete and wood storage building
Courtesy of State of Maine Department of Transportation

Conventional wood-stud wall construction encloses the bin and supports the simple lumber roof trusses above. Interior walls are sheathed diagonally with 1-in. by 6-in. (2.5-cm by 15-cm) matched sheathing. Tension cables and I-beams reinforce the structure in both directions at the eave line. Sliding wood doors, hung at the top, close the 14-ft (4.2-m) front opening. The asphalt-shingled roof is substantially pitched, with overhanging eaves to provide good weather closure.

The standard structure of this type measures 28 ft by 40 ft (8.5 m by 12 m) inside the concrete curb, with roof trusses 12 ft (3.6 m) above the floor. The design capacity is 320 tons (290 t) of salt.

One of the most interesting features of this structure is economical construction by the Maine Department of Transportation. Road crews, experienced in construction, build these structures during the fall months. The basic design features of this shed have also been incorporated into a structure that serves both as a garage and as a storage facility.

Storage Crib With Sliding Roof

The North Carolina Department of Transportation and Highway Safety has developed a simple, low-cost salt storage crib with a roof that rolls back to permit direct delivery by truck and to facilitate truck loading with a front-end loader. This feature makes the total storage capacity of this building relatively high in proportion to the size.

Constructed of reinforced concrete block, the storage crib has a retractable, wood-frame and corrugated metal roof. The block walls are built on a shallow, spread concrete footing, offset to withstand the lateral overturning forces of the salt. The crib illustrated in Figure 19 employs 12-in. (30-cm) thick block for lateral stability. If block buttresses provide this support, smaller block can be used, although maneuverability at the sides of the crib is limited by the buttresses. An alternate crib of creosoted timber is supported by 6-in. (15-cm) rolled steel I sections, which also carry the roof load. Experience has shown the creosoted timbers to be preferable because of their greater durability.

The 6-in. (15-cm) steel wheels at the front and rear corners of the roof, and at 6-ft (1.8-m) intervals between, roll on a continuous galvanized steel angle track along the top of each side wall. At the rear of the shelter, track extensions, supported vertically and horizontally by I-beams welded to the track and imbedded in concrete, are required equal in length to the maximum opening of the roof, thus increasing the total required ground area. Although the metal wheels and the track are somewhat protected by a large overhanging eave, frequent greasing of wheels, track, and extension track prevents rusting. A reinforced timber bumper and steel eye at the front end of the roof facilitate opening and closing of the roof by a front-end loader. The floor is of bituminous paving with 2-in. (5-cm) pipe drains that allow any water to escape through the walls. The inside dimensions of the structure shown are 7.5 ft by 40 ft by 18 ft (2.3 m by 12 m by 5.4 m). The capacity of approximately 225 tons (200 t) can be increased by raising the walls.

Approximately 20 of these storage cribs have been built in county road maintenance yards throughout North Carolina. When salvaged creosoted lumber and steel are used, a 225-ton (200 t) shed costs approximately the same as one built of 12-in. by 8-in. by 16-in. (30-cm by 20-cm by 40-cm) concrete blocks. If new lumber were to be used, the cost would be significantly higher.

The major feature of this design--the sliding roof--could occasionally be a disadvantage as well. Malfunctions of the sliding mechanism (very rare in actual practice) or human error could leave the salt exposed to the elements. A plastic cover should be on hand for use in case of a malfunction.

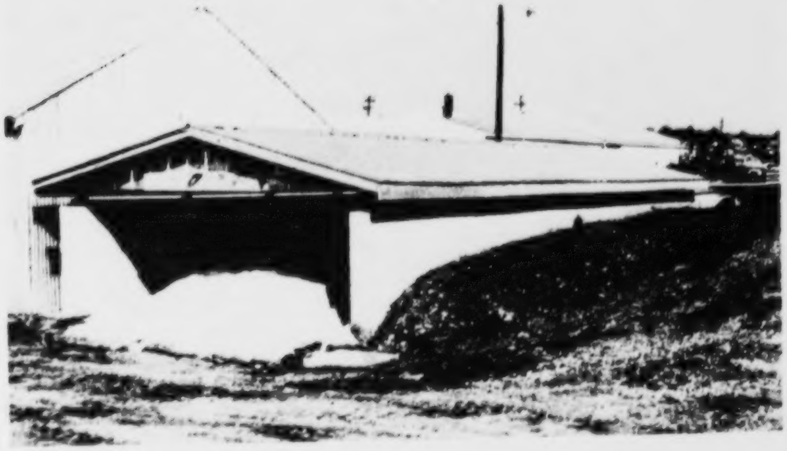


Figure 19 Storage crib with sliding roof
Courtesy of North Carolina Department of Transportation and Highway Safety, Division of Highways, Bridge Maintenance Unit

Open-Face Concrete Block and Timber Shed

The shed shown in Figure 20 is an open-face structure of concrete block and timber designed by the New York State Thruway Authority. Walls are made of cement-filled 12-in. (30-cm) concrete block, reinforced vertically through the block cells with steel that ties the block to a continuous, reinforced concrete footing, which extends to 4 ft (1.2 m) below grade. Additional internal reinforcing piers at midpoints on the side walls and quarterpoints on the rear wall provide resistance to lateral overturning forces.

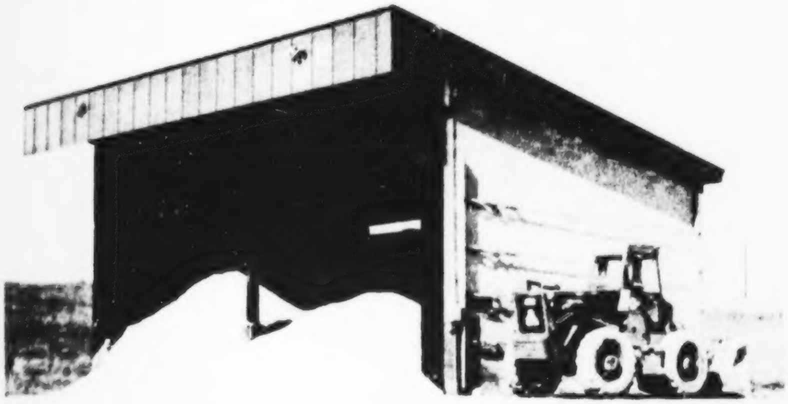


Figure 20 Open-face concrete block and timber shed
Courtesy of New York State Thruway Authority

In the middle of the open front face, an 8-in. (20-cm) steel column, bolted to a footing and protected to a height of 5 ft (1.5 m) by a reinforced concrete collar, supports the central steel roof beam. Timber joists (2 in. by 12 in., 5 cm by 30 cm) spanning from the side walls to the center beam support a diagonal tongue-and-groove timber roof deck covered with mineral surface roofing. An eave extension (1.5 ft, 45 cm) at the side and rear walls permits free ventilation between the joists and good weather closure. A 4-ft (1.2-m) high plywood and batten fascia over the wide eave at the open front helps to protect the interior from intruding weather. The roof pitches from 20 ft (6 m) in the front to 15 ft (4.5 m) at the rear wall. All steel and exterior wood members are painted. Two internal overhead lights are provided. Measuring approximately 27 ft by 38 ft (8 m by 11.5 m) internally, this shed has a design capacity of approximately 330 tons (300 t).

Although this design has proven to be satisfactory for protection of chemicals and has been quite durable, it was adopted nearly twenty years ago when present volumes of material usage were not foreseen. At the present time, alternative designs are being investigated that would have larger storage capacity and lower cost per unit volume stored.

Braced Timber Storage Shed

The shed designed by the Massachusetts Department of Public Works and shown in Figure 21 is an externally braced, timber structure, measuring 36 ft by 80 ft (11 m by 24 m) inside. The exterior walls are built of 8-in. by 8-in. (20-cm by 20-cm) pressure-treated posts [4 ft (1.2 m)] sunk 6 ft (1.8 m) below grade and secured to concrete footings. Strapping (2 in. by 4 in., 5 cm by 10 cm) between posts supports the exterior grade plywood wall sheathing.

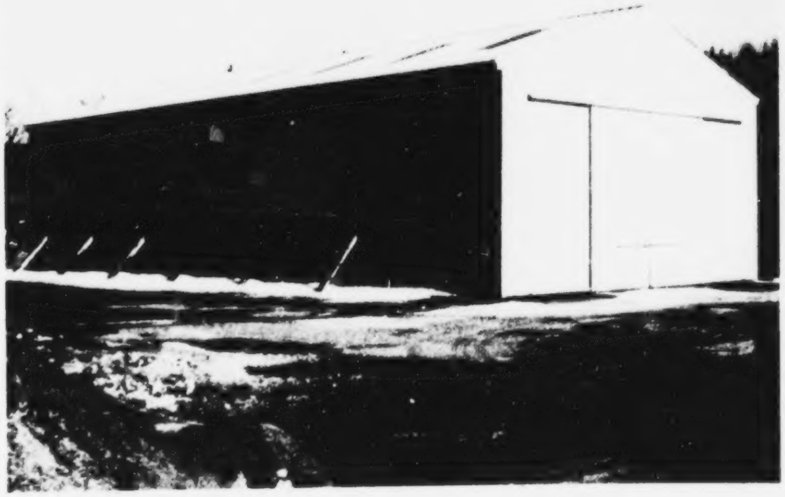


Figure 21 Braced timber storage shed
Courtesy of Commonwealth of Massachusetts
Department of Public Works

An interior bulkhead wall to a height of 8 ft (2.4 m) bears the salt load. Constructed of 8-in. by 8-in (20-cm by 20-cm) posts (placed and sunk below grade in the same manner as the exterior walls), the bulkhead has horizontal 3-in. by 8-in. (7.6-cm by 20-cm) timber planking and braced buttressing extending diagonally through the outside wall to external thrust blocks. All untreated wood members are painted or stained on the exterior of the building.

The roof is supported by timber roof trusses, beginning 16 ft (4.8 m) above the floor, stabilized by two-way bracing at each post and longitudinal sway braces between trusses along the ridge. The roof consists of aluminum panels, flashed at ridge joints and eaves. Skylight panels, equally spaced along each side of the roof, light the interior of the shed. A sliding masonite-sheathed door closes off the end opening, and louvers in the gable ends provide ventilation. The design capacity of this shed is approximately 1200 (1100 t) tons.

Dome Storage Shelter

John R. Fitzpatrick of the Department of Highways, Province of Ontario, Department of Public Works, originally designed this storage shelter, which is marketed in the U.S. by Domar Modular Systems, Inc., of Utica, New York.

The dome (Figure 22) is a 20-sided cone constructed of factory-produced modules of 3/8-in. (0.9-cm) plywood and 2-in. by 6-in. (5-cm by 15-cm) lumber, which are bolted together at the building site. Each of the 20 sides consists of nine panels forming an isosceles triangle with a ventilation duct near the top. Since the dome is its own structural support, loading and unloading operations are not hampered by internal supports. However, as with any structure with a sharply sloping roof, care must be exercised during operation of a front-end loader near the walls.

Covered with relatively maintenance-free asphalt shingles, the structure sits on a floating concrete ring placed directly on an asphalt or concrete pad. Around the interior of the dome, a retaining ring, supported by posts imbedded in the floor pad, keeps the material away from the base of the structure. This retaining wall is 4 ft (1.2 m) in all units sitting directly on a floating ring.

The Domar structure is designed primarily as a cover rather than a container for a pile of salt or sand and as such is not designed to bear the salt load. The angle of the walls conforms to the angle of repose of the material being stored--38 degrees for salt or 45 degrees for moist sand; the latter angle is used most frequently. Filling up to 100% of storage capacity is possible with a belt conveyor loading through a hatch near the top or with a throwing system from below. More common practice with a front-end loader fills the structure up to a maximum of 80% of capacity.

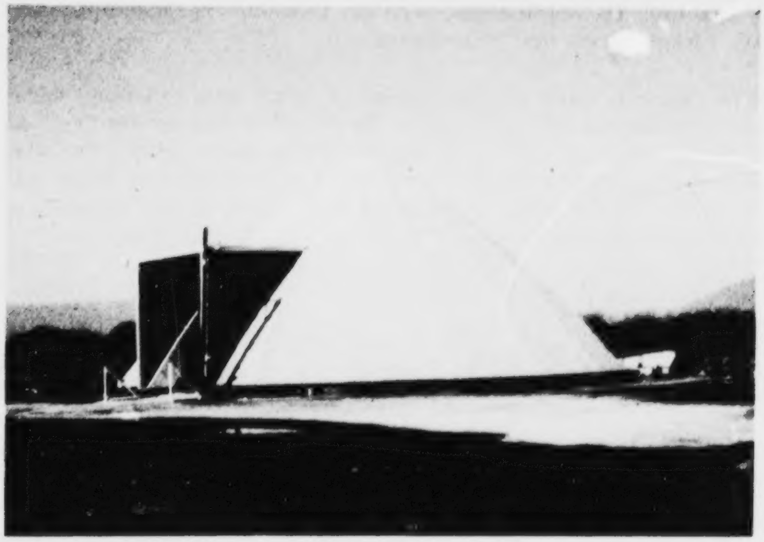


Figure 22 Dome storage shelter
Courtesy of Domar Modular Systems, Inc.,
Utica, New York

Available in seven sizes, Domar bulk storage sheds range in diameter from 51 ft (15.5 m) [capacity of 350 tons (317 t) of salt] to 150 ft (45 m) [capacity of approximately 16,000 tons (14,500 t)]. The purchaser provides the pad and prepares the site to specifications. Varying price schedules are available if the purchaser provides the foundation and/or erects the structure. Approximately 900 man hours are required to complete a dome on a concrete pad previously laid.

In the Province of Ontario where the design originated, the Ministry of Transport has 100 units in use. Approximately 40 units are under construction or already in use in the United States, primarily in Pennsylvania, California, Michigan, Ohio and Indiana. A new large-scale storage shed, a barrel building, that has been developed is the basic dome unit cut in half and joined by incremental 8-ft (2.4-m) modules.

Creosoted Timber Storage Shed

A shed of creosoted timber is available commercially (Wheeler, Minneapolis, Minn.) in a pre-engineered (all materials, hardware, and working plans) package for construction by the purchaser or his contractor. These sheds, such as the one in Figure 23, are in use in the Midwest, primarily in Wisconsin, Michigan, and Minnesota.

The design uses braced timber framing with the primary structure of 6-in. by 12-in. (15-cm by 30-cm) posts [4 ft (1.2 m) on center] and galvanized tension cables tying together every other pair of posts across the top and under the paving surface. Posts are set firmly to 4 ft (1.2 m) below grade in post holes that are backfilled to maximum density; in some cases concrete footings are used.

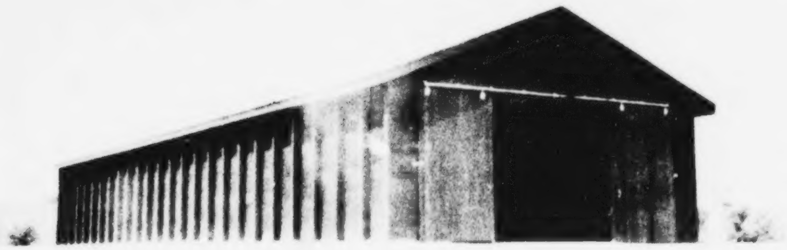


Figure 23 Creosoted timber storage shed
Courtesy of Wheeler Lumber, Bridge, and Supply Company, Minneapolis, Minnesota

Inside the posts, sheathing of 3-in. by 12-in. (8-cm by 30-cm) horizontal planks is used to a height of 8 ft (2.4 m) above the floor, with 2-in. by 12-in. (5-cm by 30-cm) planks from that height up to the roof trusses. The roof is supported by simple timber trusses at each post with wood gussets at connections. Knee braces at 16-ft (4.8-m) intervals stabilize the structure transversely; diagonal braces in the walls and horizontal braces at eave height at each corner provide additional reinforcing. The roof consists of galvanized roll roofing on wood purlins or 30-pound felt and asphalt on plywood, with vent space at the eaves and louvers at the gable ends. All timber members are pressure-treated. A 14-ft (4.2-m) wide bi-parting sliding wooden door on metal guides closes exterior openings. A floor of bituminous paving is provided by the purchaser.

This shed is available in a variety of sizes, with a standard width of 30 ft (9 m); heights of 12, 14, or 16 ft (3.6, 4.2, or 4.8 m); and length variable in 4-ft (1.2 m) increments (each containing approximately 44 tons or 40 t). A structure with 920-ton (835-t) capacity measures 30 by 84 by 14 ft (9 by 25 by 4.3 m). One shed design has several doors positioned along one side; more common is a standard layout with both front and rear doors. Another popular design has no doors at the openings.

OTHER STORAGE PRACTICES

Under Viaducts

A particularly convenient and economical method of salt storage utilizes the cover provided by a viaduct as is shown in Figure 24. Piles stored in this manner should be located away from prevailing wind and precipitation, preferably under a wide road. A bituminous pad must be provided, and any drainage from the road bed must be diverted away from the pile. Similarly, the pile should not be located under expansion joints where water from the roadway can drip through or near vertical structural members of the viaduct that might be corroded. Depending on the degree of protection afforded by the viaduct, a cover should be provided for the pile, at least on the weather side.

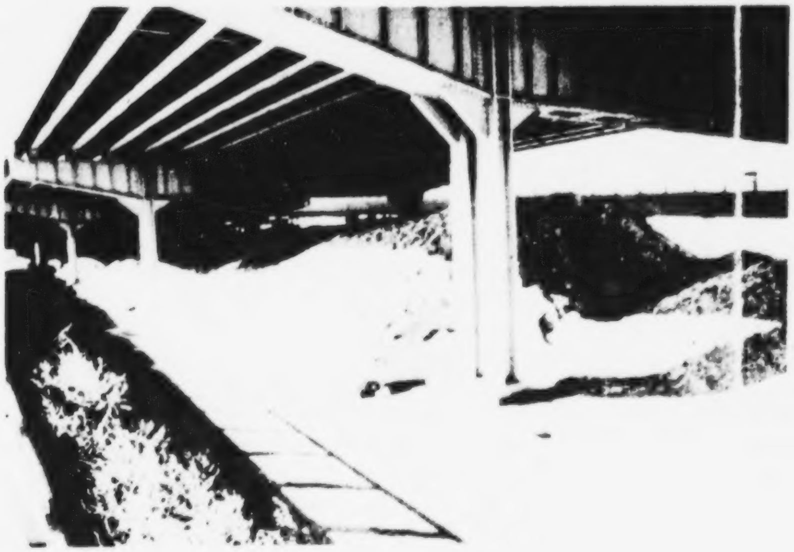


Figure 24 Salt storage under a viaduct

Covered Salt Pile

Storage of salt in an outside, covered stockpile is a very commonly used, low-cost method; among large salt distributors this is common practice. The salt is piled and allowed to assume its natural angle of repose (32 degrees from horizontal) on a bituminous concrete pad; larger piles are often windrow-shaped with conical ends. Sometimes cribs or bins are constructed of materials such as telephone poles or railroad ties to help contain the pile.

Numerous covering materials have been used, including polyethelene (often reinforced with nylon or wire or coated with asphalt and burlap), canvas, jute, roofing paper, cutback asphalt, and vinyl. Any cover that is completely waterproof is suitable.

Cover materials are very vulnerable to damage; a great deal of care is required to maintain adequate cover during and after loading and unloading operations, and all too often salt is left exposed to wind and moisture.

A notable exception to the common experience with covered salt piles was observed at a storage area of Chemical Corporation, a wholly owned subsidiary of the Morton Salt Company, in Westfield, Massachusetts. Located on a railroad siding, the area contains meticulously maintained outdoor storage for 72,000 tons (65,000 t) of salt.

As shown in Figure 25, two parallel windrow-shaped piles (80 to 90 ft by 500 to 600 ft or 24 to 27 m by 152 to 183 m) are carefully built up with a conveyor belt on asphalt pads sloped away from the pile. Materials for covering outdoor piles have been developed over the past 20 years by Chemical Corporation. Currently, a canvas tarpaulin material is used for permanent cover, with other cheaper materials used to cover more frequently used portions of the pile. These latter materials include netting-reinforced black polyethelene (15-ft or 4.5-m wide) with a paper cover (which faces the weather) and 11.5-ft (3.5-m) wide tarpaulin materials consisting of an asphalt-impregnated, randomly oriented polyproplyene fiber mat between two outer layers of paper or mildew-treated burlap adhered to a clear polyethelene sheet with a thick coating of black asphalt. Individual strips are stitched together with a hand-held electric sewing machine, and the entire cover is weighted around the base of the pile with used automobile and truck tires. In places where the pad is not properly sloped to control runoff water, the tarpaulin cover is cemented to the pad with hot asphalt. Whenever possible the cover is folded back during loading and unloading and repositioned at the end of the day. When heavy ice and snow coat the cover, it is merely ripped off the pile and discarded. A lightweight cover is used to cover the open end of the pile as soon as possible after loading operations are finished.

As shown by the procedures used in this storage area, good practice in outdoor storage requires considerable and continual diligence and devotion on the part of personnel maintaining the storage.

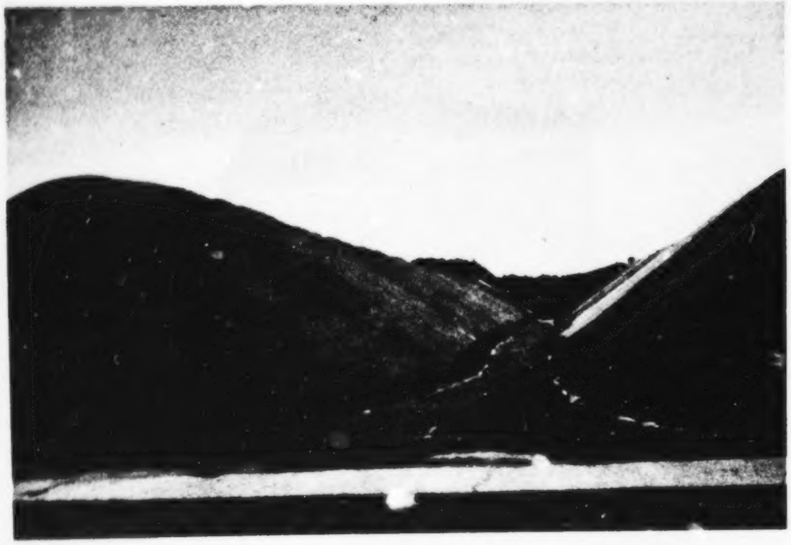


Figure 25 Covered outdoor storage piles
Courtesy of Chemical Corp., Westfield, Massachusetts

Overhead Hoppers

Overhead hoppers combine both the storage and truck loading functions with a minimal requirement for manpower and equipment. Hoppers are common practice in England and in some parts of the U.S. where they are used most effectively when the hopper capacity is sufficient for each large storm and refilling is performed between periods of high salt usage.

Hopper capacity averages 100 tons (90 t). Sometimes built into the side of a hill to facilitate filling by salt delivery trucks, hoppers are more commonly elevated on a steel frame structure and filled pneumatically. The Alta-type bunker shown in Figure 26 has a capacity of 100 tons (90 t), costs approximately $20,000, is of steel construction, and is loaded by pneumatic salt delivery trucks. Salting trucks drive beneath the hopper, and salt is withdrawn by gravity through a clamshell opening that is controlled manually by the truck driver.

Experience with hoppers has been good; mechanical problems are rare. In many locations, however, front-end loaders are already available, and

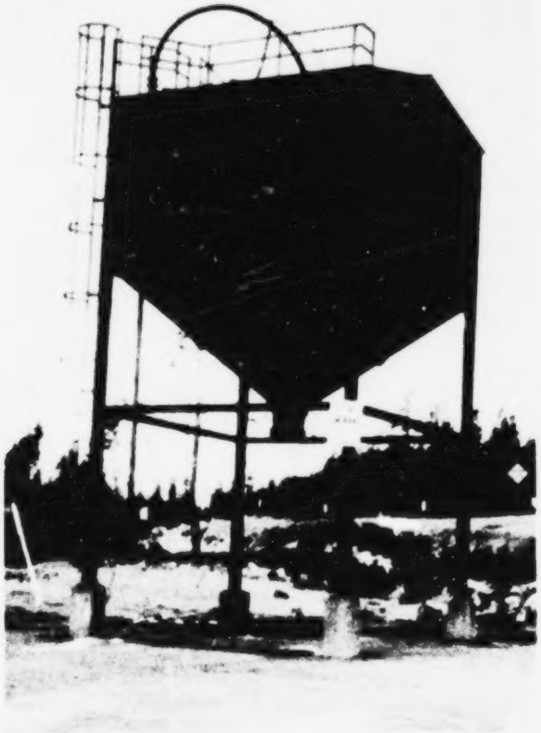


Figure 26 Alta-type 100-ton storage hopper
Courtesy of State of California
Department of Transportation

storage sheds have proved to be more economical. This is especially true if the salt requirements are so high during peak periods that the hoppers must be filled frequently.

PRACTICES TO BE AVOIDED

When good practice in salt storage is the goal, any procedure that has a high probability of failure should be avoided. More specifically the chances for human error and mechanical failure must be minimized.

In the storage facilities visited during this study, bad practice in salt storage was most often associated with outdoor storage in either uncovered (undesirable in any case) or covered piles. In the case of the latter, the meticulous maintenance required for good outdoor storage was frequently lacking. Covered piles maintained out of doors are very vulnerable to damage. Covers are easily ripped during handling or improperly anchored and blown off by high winds.

Another practice that should be avoided is any procedure that relies on intricate mechanical systems. A good example of this has been the experience with grain silos.

Experience with glass-lined grain silos for storage and handling of road salt has not been successful. Salt is not only heavier than the most common feed grains [80 lb per ft^3 (1280 kg per m^3) as opposed to 48 lb per ft^3 (769 kg per m^3)] but also has different characteristics, dimensions, and physical properties that are not well adapted to the grain handling mechanisms in storage silos. The unloading mechanism in commonly used storage silos utilizes a reciprocating table to move grain from the exit funnel of the silo to the bucket elevator, which raises it to a discharge chute, which in turn guides the grain to a waiting truck. These two mechanisms, particularly the reciprocating table, are subject to jamming with salt.

When salt is stored longer than a few weeks, there is a possibility of a plug of solidified material forming within the silo, impeding flow of material. Similarly, salt with sufficient moisture can freeze and form a plug. This plug is very difficult to remove or break up. Like the overhead hopper, the grain silo often has insufficient capacity particularly during heavy winter storms when its capacity can be easily used up in a few hours. Thus resupply of the silo becomes necessary.

DESIGNING FOR DURABILITY

Designs for salt storage sheds must take into account inevitable mistakes with or mishandling of mechanical loaders, as well as the considerable wear and tear of normal operations. As mentioned previously, any portion of the structure within reach of the front-end loader is vulnerable to damage; appropriate choice of construction materials for these areas and maximum possible reinforcement are important.

The corners of any salt enclosure are particularly vulnerable when the front-end loader is working close to the walls. In some shed designs, a concrete curb or parapet extends up the walls as far as 4 or 5 ft (1.2 or 1.5 m) beneath a lighter, more vulnerable wood or metal structure above. Timber bulkheads or bumpers are often used for protecting corners and lower walls in concrete block sheds or in wooden structures, especially those with arched or conical roofs within reach of the front-end loader.

Door jambs and lintels are also natural targets for damage during loading and unloading operations. Both can be reinforced structurally (e.g.,use of double timber or metal posts). In addition, the surfaces can be protected by metal pipe columns, or in the case of door jambs, by cast iron wheel guards.

Another important consideration in designing storage sheds is to minimize maintenance. Use of creosoted timber eliminates the need for painting of exposed wooden exteriors. More important, in lower walls that have a good chance of coming into frequent contact with water, creosoting prevents rotting of timbers.

ECONOMIC CONSIDERATIONS

Cost of Specific Designs Shown

Whenever possible construction costs were obtained for the representative storage sheds shown previously. These figures summarized in Table 1, include inside dimensions, estimated and quoted storage capacities of each building, and cost per ton of salt storage, based on the estimated capacity. Variables such as local availability and costs of materials could not be standardized; insofar as these are known, they are indicated in footnotes.

In Figure 27, the cost figures per ton of storage capacity are plotted against shed capacity.

Cost Savings

Considerable cost savings are possible through a variety of techniques observed during this study.

Choice of appropriate and economical materials is crucial. Salvaged materials or mass-produced items such as telephone poles and railroad ties have been incorporated successfully into numerous salt storage facilities.

Within some jurisdictions, the highway department provides the labor for design and for construction of salt storages, thus eliminating the need for an outside contractor.

Multiple use of storage facilities can also be advantageous. Some structures with multiple bays are ideally suited for use as garages or for storage of other materials or equipment during summer months, although some corrosion of equipment is possible.

One possibly economical approach to enclosed salt storage would be use of other commercially available, mass-produced structures. With a suitable floor and interior load-bearing bulkhead, such as those used in the sample storages shown in this manual, any other type of inexpensive structure could be converted to use as a salt storage.

ESTIMATING CAPACITY

The actual capacity of any salt storage is determined by the amount of material that can be placed into the space, as well as the ability of the loading mechanism to utilize efficiently the available space.

Table 1. SUMMARY OF CAPACITIES AND COSTS OF SALT STORAGE BUILDINGS

Storage building	Quoted cap. (tons)	Int. dimensions (ft)				Volume (yd^3)			Capacity		Cost[a] ($)	Cost per ton est. salt capacity ($)
		w	l	h_{max}	h_1	Max.	Usable	[m^3]	(tons)	[t]		
Mass. Turnpike Wooden Arch	1000	54	78	25	5	3300	1620	[1239]	1750	[1588]	35,000[b]	20
Mass. Turnpike Wooden Rigid Frame	1500	56	77	25	6	3900	1780	[1361]	1925	[1746]	50,000[b]	26
California Dual Storage		50	79	16	7	2300	1610	[1231]	1740	[1579]	133,000[c]	65
		19	50	16	7	560	290	[222]	310	[281]		
Maine Concrete and Wood	320	28	40	12	4	500	260	[199]	285	[259]	6,200[d]	22
North Carolina Crib with Sliding Roof	225	18	40	8	8	210	180	[138]	195	[177]	7,200[e]	37
N.Y. Thruway Open Face, Concrete Block	300	38	27	20	14	650	310	[237]	330	[299]	22,000[f]	66
Massachusetts DPW Braced Timber	1200	36	80	18	8	1900	1175	[898]	1270	[1152]	21,000[g]	17
Domar Dome	350	51			3	480	360	[275]	390	[354]	11,000[h]	28
	700	61			3	800	600	[459]	650	[590]	14,500	22
	1200	72			3	1300	975	[745]	1060	[962]	18,000	17
	1800	82	Diameter		3	1900	1430	[1093]	1540	[1397]	24,000	16
	3400	100			3	3390	2540	[1942]	2750	[2495]	30,000	11
	5000	116			3	5280	3920	[2997]	4230	[3837]	42,000	10
	14000	150			3	11000	8250	[6308]	8970	[8137]	100,000	11
Wheeler Creosoted Timber	500	28	39	16	14	600	430	[329]	465	[422]	16,000[i]	34
	920	28	83	16	14	1300	1150	[879]	1240	[1125]	20,000	16
	3000	48	120	16	14	3200	3020	[2309]	3260	[2957]	36,500	11

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[a] Paving not included.

[b] Paving included, construction by outside contractor.

[c] Seismic stressing and high snow loading (3000-ft elevation).

[d] Labor by Maine DOT personnel.

[e] Salvaged timber and steel.

[f] Heavy steel reinforcing.

[g] Construction by outside contractor.

[h] Cost for erected shelter. Purchaser may supply foundation and erect structure at reduced cost.

[i] Cost for erected shelter.

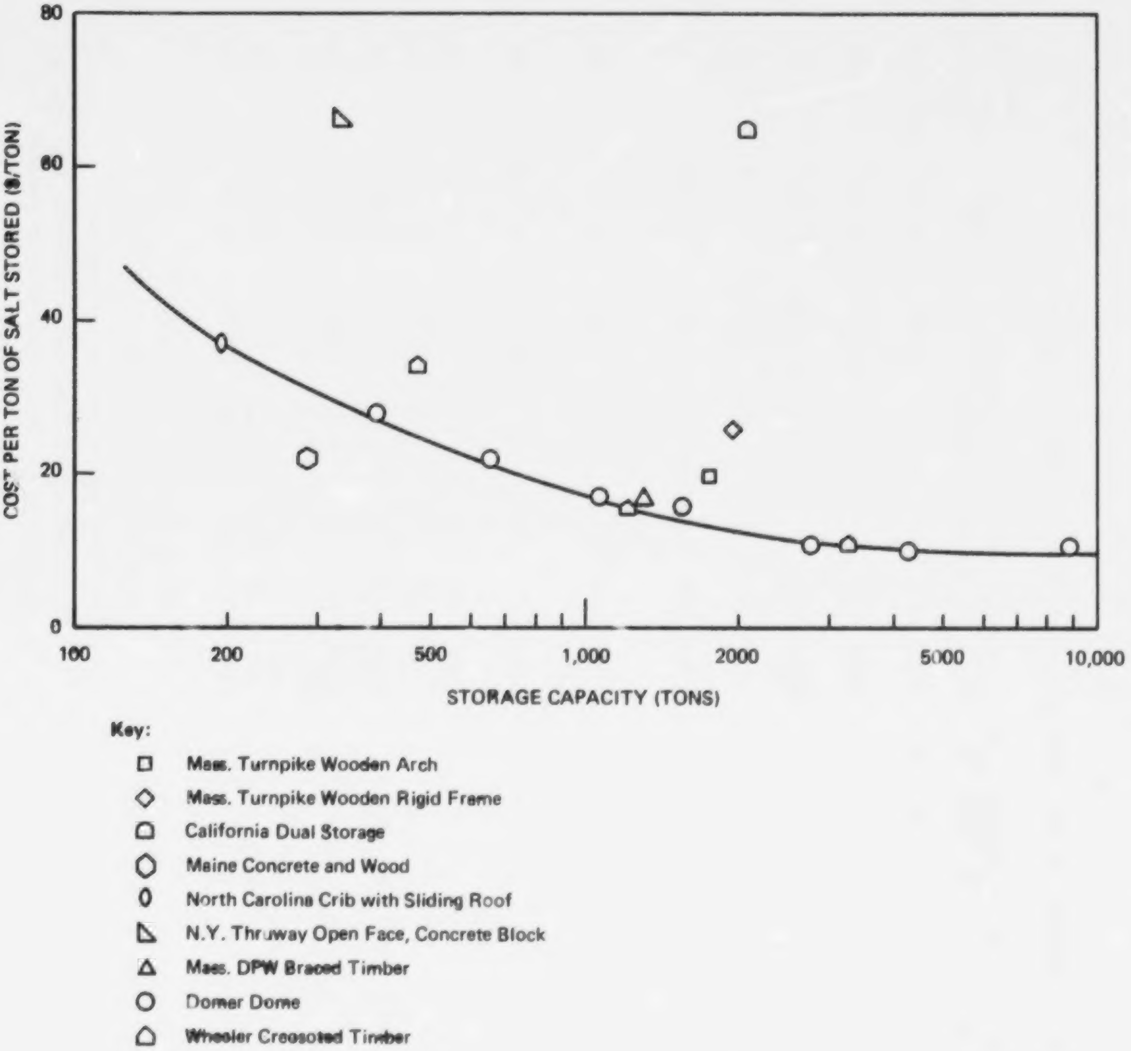


Figure 27 Summary of salt storage building costs

It is often desirable to calculate the area and/or volume required for storage of salt, calcium chloride, sand, cinders and various mixtures of these. Likewise, it may be necessary to calculate the amount of material that can be stored safely in a given building or area. The starting point in all of these calculations is the listing of the properties of materials found in Table 2.

TABLE 2: PROPERTIES OF MATERIALS

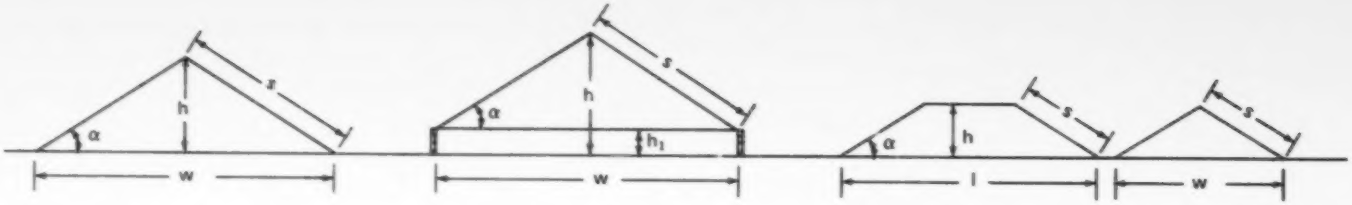
		Dry Salt	Calcium Chloride	Sand	Cinders
Chemical formula		$NaCl$	$CaCl_2$	dry	dry
Bulk Density (p)	lbs/ft^3	80	55-65	90-100	40
	ton/yd^3	1.08	0.74-0.88	1.2-1.4	0.54
	kg/m^3	1280	880-1040	1440-1600	640
Angle of repose (from horizontal)		32°	25-30°	34°	40°

The ground area, volume, and surface occupied by several basic shaped piles of salt are summarized in Figure 28. These shapes include a conical pile, a conical pile on a cylindrical base, a peaked windrowed pile, a flat-top windrowed pile, and two complex shapes representing typical salt storage shed practice. The capacity of other complex salt storage sheds may be estimated by means of volume formulae for these basic shapes.

The characteristics of conical and windrow salt piles containing varying amounts of salt are summarized in Tables 3 -A and -B and 4 -A and -B (for each table, A gives British units and B gives metric units). The table for the storage capacity in windrow piles gives the capacity only for the windrow section of the pile. The dimensions of the conical shaped end sections of a windrow can be obtained from Table 3.

Loading and unloading procedures limit the full utilization of available storage space. The most commonly used means, the front-end loader, is most effective within specific height ranges. In operation, the front-end loader has difficulty scaling piles of salt for any distance and, therefore, cannot pile salt significantly higher than the reach of its bucket without the aid of a temporary ramp formed in the salt already in the building.

Blowers, throwers, conveyor belts, or any other means of building a salt pile from above enable more efficient use of available storage space. This is illustrated very well by experience with dome structures (such as the Domar shed) with sloping sides at the angle of repose of salt. Although a front-end loader can fill the space to 70% - 80% capacity, a thrower or conveyor system can fill the shed to its theoretical capacity.



	CONICAL PILE	CONICAL PILE ON A RETAINING RING	POINTED-TOP WINDROW PILE
Limitations on the equations	$h = \frac{w}{2} \tan \alpha$	$h - h_1 = \frac{w}{2} \tan \alpha$	l must be greater than w, $h = \frac{w}{2} \tan \alpha$
Maximum height of the pile h	$\frac{w}{2} \tan \alpha$	$h_1 + \frac{w}{2} \tan \alpha$	$\frac{w}{2} \tan \alpha$
Length of the sloped part of the pile s	$\frac{w}{2 \cos \alpha}$	$\frac{w}{2 \cos \alpha}$	$\frac{w}{2 \cos \alpha}$
Area occupied by the pile A	$0.785(w)^2$	$0.785(w)^2$	$wl - 0.215(w)^2$
Exposed surface area A_S	$\frac{0.785(w)^2}{\cos \alpha}$	$\frac{0.785(w)^2}{\cos \alpha}$	$\frac{w}{\cos \alpha}(l - 0.215w)$
Volur..e of the pile V	$0.131(w)^3 \tan \alpha$	$0.131(w)^3 \tan \alpha + 0.785(w)^2 h_1$	$0.25w^2 (l - 0.476w) \tan \alpha$
Tons of Salt $\alpha = 32^{\circ}$ ρ = 80 lbs/cu. ft.	$0.00327(w)^3$	$0.00327(w)^3 + 0.0314(w)^2 h_1$	$0.00625w^2 (l - 0.476w)$

Figure 28 Calculation of storage characteristics of six shapes of storage piles

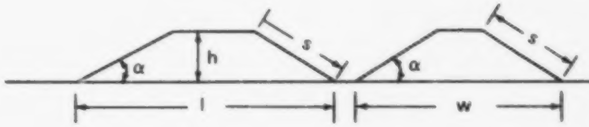
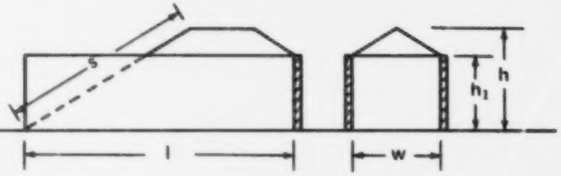
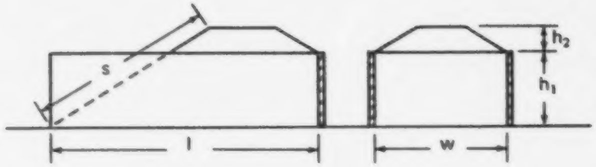
		FLAT-TOP WINDROW PILE	THREE-SIDED RECTANGULAR BIN WITH A POINTED-TOP PILE ABOVE THE RETAINING WALL AND AN OPEN FACE
			
Limitations on the equations		l and w must both be greater than $\frac{2h}{\tan\alpha}$	l must be greater than $(w + \frac{h_1}{\tan\alpha})$, $h - h_1 = \frac{w}{2} \tan\alpha$
Maximum height of the pile	h	h	$h_1 + \frac{w}{2}\tan\alpha$
Length of the sloped part of the pile	s	$\frac{h}{\sin\alpha}$	$\frac{h_1}{\sin\alpha} + \frac{w}{2\cos\alpha}$
Area occupied by the pile	A	$wl - 0.858 \frac{h^2}{\tan^2\alpha}$	wl
Exposed surface area	A_S	$\frac{2h}{\sin\alpha}(w + l - \frac{2.43h}{\tan\alpha})$	$\frac{wl}{\cos\alpha}$
Volume of the pile	V	$\frac{h^2}{\tan\alpha}(l + w - 2.953\frac{h}{\tan\alpha}) + h(l - \frac{2h}{\tan\alpha})(w - \frac{2h}{\tan\alpha})$	$wh_1(l - \frac{h_1}{2\tan\alpha}) + 0.25w^2(l - \frac{h_1}{\tan\alpha} - 0.333w)\tan\alpha$
Tons of salt $\alpha = 32^o$ $\rho = 80$ lbs./cu.ft.		$0.64h^2(l + w - 4.74h) + .04h(l - 3.2h)(w - 3.2h)$	$0.04wh_1(l - 0.8h_1) + 0.00624w^2(l - 1.6h_1 - 0.333w)$

Figure 28 Continued

THREE-SIDED RECTANGULAR BIN
WITH A FLAT-TOP PILE ABOVE
THE RETAINING WALL AND AN OPEN FACE



Limitations on the equations		l must be greater than $\frac{h_1 + 2h_2}{\tan\alpha}$ and w must be greater than $\frac{2h_2}{\tan\alpha}$
Maximum height of the pile	h	$h_1 + h_2$
Length of the sloped part of the pile	s	$\frac{h_1 + h_2}{\sin\alpha}$
Area occupied by the pile	A	wl
Exposed surface area	A_S	$\frac{wh_1}{\sin\alpha} + \frac{2h_2}{\sin\alpha}\left(w + l - \frac{h_1}{\tan\alpha} - \frac{2.00h_2}{\tan\alpha}\right) + \left(w - \frac{2h_2}{\tan\alpha}\right)\left(l - \frac{h_1}{\tan\alpha} - \frac{2h_2}{\tan\alpha}\right)$
Volume of the pile	V	$wh_1\left(l - \frac{h_1}{2\tan\alpha}\right) + \frac{h_2^2}{\tan\alpha}\left(w + l - \frac{h_1}{\tan\alpha} - 2.67\frac{h_2}{\tan\alpha}\right) + h_2\left(w - \frac{2h_2}{\tan\alpha}\right)\left(l - \frac{h_1}{\tan\alpha} - \frac{2h_2}{\tan\alpha}\right)$
Tons of Salt $\alpha = 32^\circ$ $\rho = 80$ lbs./cu. ft.		$.04wh_1(l - .8h_1) + .064h_2^2(w + l - 1.2h_1 - 3.2h_2) + .04(w - 2.4h_2)(w - 1.2h_1 - 2.4h_2)$

Figure 28 Continued

TABLE 3A CHARACTERISTICS OF SALT IN CONICAL PILES

(BRITISH UNITS)

Tons of Salt	Diameter (ft)	Area (ft^2)	Height (ft)	Length (ft)	Volume (ft^3)	Exposed Area
25	20	305	6	11.5	625	360
50	25	483	8	14.5	1250	570
75	28	633	9	17	1875	750
100	31	764	9.5	18	2500	900
200	39	1210	12	23	5000	1430
300	45	1600	14	26.5	7500	1880
400	50	1930	16	29	10000	2220
500	53	2240	17	31.5	12500	2640
600	57	2520	18	33.5	15000	2980
700	60	2800	19	35	17500	3300
800	63	3070	20	37	20000	3620
900	65	3310	20.5	38	22500	3900
1,000	67	3560	21	39.5	25000	4200
2,000	85	5650	26	50	50000	6660
3,000	97.0	7390	30	51	75000	8710
4,000	107	8950	33	63	100000	10200
5,000	115	10400	36	68	125000	12200
6,000	122	11720	38	72	150000	13800
7,000	129	13000	40	76	175000	15300
8,000	135	14200	42	79	200000	16700
9,000	140	15400	44	82.5	225000	18100
10,000	145	16500	45	85	250000	19400

TABLE 3B CHARACTERISTICS OF SALT IN CONICAL PILES

(METRIC UNITS)

Metric Tons of Salt	Diameter (m)	Area (m^2)	Height (m)	Length (m)	Volume (m^3)	Exposed Area (m^2)
25	6.2	30	1.9	3.6	19.5	35.3
50	7.8	47.6	2.4	4.6	39.0	56.1
75	8.9	62.5	2.8	5.2	58.6	73.6
100	9.8	75.5	3.1	5.8	78.1	88.9
200	12.4	120	3.9	7.3	156	141
300	14.2	151	4.4	8.3	234	185
400	15.6	191	4.9	9.2	312	225
500	16.8	221	5.2	9.9	391	261
600	17.8	250	5.6	10.5	469	294
700	18.8	277	5.9	11.1	547	326
800	19.6	302	6.1	11.6	625	356
900	20.4	327	6.4	12.0	703	386
1000	21.1	351	6.6	12.4	781	413
2000	26.6	556	8.3	15.7	1560	656
3000	30.5	729	9.5	18.0	2340	860
4000	33.5	883	10.5	19.8	3130	1040
5000	36.1	1020	11.3	21.3	3900	1210
6000	38.4	1160	12.0	22.6	4690	1360
7000	40.4	1280	12.6	23.8	5470	1510
8000	42.2	1400	13.2	24.9	6250	1650
9000	43.9	1510	13.7	25.9	7030	1790
10,000	45.5	1620	14.2	26.8	7810	1920

TABLE 4A CHARACTERISTICS OF SALT IN WINDROWED PILES (POINTED TOP)

(IN BRITISH UNITS)

Windrow Width (ft)	Height (ft)	Volume (ft)	Exposed A (ft^2)	Tons of Salt
20	6.2	62.4	23.8	2.5
30	9.4	140.6	35.7	5.6
40	12.5	249.8	47.6	10.0
50	15.6	390.5	59.5	15.6
60	18.7	562.2	71.4	22.5
70	21.9	765.5	83.3	30.6
80	25.0	999.6	95.2	40.0
90	28.1	1264.9	107.1	50.6
100	31.2	1562.0	119.0	62.5
110	34.4	1889.8	130.9	75.6
120	37.5	2249.4	142.8	90.0
130	40.6	2639.6	154.7	105.6
140	43.7	3061.8	166.6	122.5

TABLE 4B CHARACTERISTICS OF SALT IN WINDROWED PILES (POINTED TOP)

(IN METRIC UNITS)

Windrow Width (m)	Height (m)	Volume (m^3)	Exposed Area (m^2)	Metric Tons of Salt
10	1.0	0.36	11.8	0.46
15	1.4	0.54	17.7	0.69
20	1.9	0.73	23.6	0.93
25	2.4	0.91	29.5	1.16
30	2.9	1.08	35.4	1.38
35	3.4	1.27	41.3	1.62
40	3.8	1.45	47.2	1.86
45	4.3	1.63	53.1	2.08
50	4.8	1.81	59	2.31

PART THREE: HANDLING OF DEICING CHEMICALS

CHAPTER V

GENERAL PRECAUTIONS IN HANDLING

Three general precautions apply to all aspects of salt handling, from receiving material to loading trucks for out-shipment:

1. Keep the area clean. Immediately after any handling operation, sweep off salt collected on loaders, conveyors, truck bodies, etc. Then clean up any salt lying on the pad and get it back under cover.

2. Keep the salt dry. Keep salt under cover if possible at all times. Covering prevents brine runoff and caking. Keeping the pile dry is particularly important for mixtures containing calcium chloride, which absorbs water even from moist air. Preferably, unloading and loading should be done within the storage shed. If this is not possible, avoid handling during inclement weather.

3. Handle salt as little as possible. Road salt (ASTM Grades 1 and 2) contains a variety of particle sizes. When salt is handled, large particles break down to finer particles, which tend to settle out, blow off, and wash away. Neither fine nor coarse particles, by themselves, are as effective for clearing as a mixture of sizes.

The central aim of these precautions is to prevent the loss of salt and damage to equipment and the environment.

Salt lying loose around the work area is liable to be blown about by winds. It lodges in crevices in equipment and increases corrosion. It may spread to nearby lands and buildings, causing protests from neighbors. A messy pad area makes the operation appear suspect as a source of pollution, even if this suspicion is unjustified.

Salt exposed to rain and snow cakes up into big chunks which are impossible to use without being broken up. Some salt washes away, hopefully collecting as brine or particulate in a catchment (assuming that the pad area is properly sloped and drained, as described in Chapter III). Material lost through runoff represents lost dollars.

So, in handling salt, keeping the area clean and the salt pile covered are the two cardinal principles. How the principles are applied depends on what part of the whole storage and handling operation is being performed. For the sake of the discussion in the remainder of Part Three, the total operation is described in four parts: planning for next season, receiving and storing new material, mixing materials, and loading spreader or delivery trucks.

CHAPTER VI

PLANNING FOR NEXT SEASON

PRESEASON INVENTORY

The time for effective planning for storage and handling of deicing chemicals and anti-skid material is during the early spring. With all of the problems of the previous winter fresh in mind, one can plan to minimize them the next winter. Reevaluation of storage techniques, delivery schedules, loading techniques, material mixes, equipment, and manpower at this time will allow maximum lead time for implementing necessary changes.

If the snow and ice control program is being expanded, additional storage capacity may be required. Maybe an old loader is too small or slow, and trucks are always waiting during a storm to be loaded. Perhaps two or three of the best men will retire this year. In any event, this is the best time to initiate any action that will make the next winter season's handling operations run more smoothly.

Some of the points to be considered in this end-of-the-season review are:

Equipment and Facilities in Current Inventory

1. Are they effective?
2. Are they reliable?
3. If not, should recommendations for new equipment purchase or facility construction be considered?

Manpower

1. Are there enough people to do the job?
2. Are they trained well enough?
3. Should there be any personnel reassignment?

Scheduling

1. Were delivery schedules convenient?
2. Will spreader truck timing change due to changes in plowing and salting priorities next season?
3. Is the storm-warning system giving adequate preparation time?

When reviewed early, these and other problem areas unique to the operation may be ironed out before the next snowfall.

EQUIPMENT

The equipment commonly used for stockpiling and subsequent loading of deicing and anti-skid materials are: front-end bucket loaders, both rubber-tired and track-laying, bulldozers, conveyor belts, and material throwers.

Of these, the rubber-tired, front-end loader is the equipment of choice for this type of material handling. The articulated version of this machine (hinged in the middle) provides maximum maneuverability for a given sized machine. Not only is it useful for loading and unloading salt and sand, it can also be used for keeping the stockpile area and approaches clear of snow and year-round for a variety of construction and maintenance tasks. Providing this machine with two different bucket sizes results in savings of time and wear on equipment that outweigh the added original cost. A small-volume bucket will prevent overloading of the machine during the summer season, and a larger bucket will increase productivity when salt, sand and snow are being handled. The machine of preference is rated at 1.5 yd^3 (1.1 m^3) which, for winter operations, could be equipped with a 2-yd^3 (1.5-m^3) bucket. Machines with 4-yd^3 (3.1-m^3) or larger buckets are often used by salt suppliers and distributors for loading large delivery trucks. There is no advantage in using these larger machines for loading the common 5-yd^3 (3.8-m^3) truck-mounted spreaders.

Although bulldozers may be used for sand and sand/salt mixture stockpiling, they are not suited to the task of stockpiling material in storage sheds. They suffer two disadvantages of track-laying equipment, i.e., low speed and high maintenance costs.

The conveyor belt is the most efficient means for handling material. However, it requires special building and storage area design, auxiliary feeding devices including front-end loaders and it is quite expensive.

Material throwers are inexpensive and mobile; in addition, they can stack the material higher and thus make maximum use of available storage space. However, since they have been developed only recently, problems still may require ironing out. At least one major spreader manufacturer has prototype units that will move from 1 to 3 tons (.9 to 2.7 t) of salt per minute. This unit throws salt 60-80 ft (18-24 m) and enables more efficient use of storage capacity. This single-purpose machine can be used only for loading of storage sheds.

ESTIMATING QUANTITIES

The quantity of deicing chemicals required during any one winter season is completely dependent upon the weather conditions. Long-range forecasting of these weather conditions is problematical at best. Guidelines for estimating future salt needs are presented in the Manual for Deicing Chemical Application Practices[2] which outlines techniques for estimating needs from records of past usage by area, by sub-area, and by road segment. Some general rules should be applied when estimating needs:

1. Inventory the amount of salt remaining from the previous season.
2. Calculate the amount of salt or chemical used in previous seasons.
3. Take into account new mileage responsibilities added to the road or street system, including routes acquired from other jurisdictions or road areas.

ORDERING AND SCHEDULING

Although the salt and other chemicals required for a deicing and snow control program are needed only during the winter months, attention to procuring bids for required amounts and stockpiling of these materials must, of necessity, occur many months prior to the winter season. The timetable for soliciting bids for material and receiving these materials into storages should fit the budgeting and normal procurement cycle of the agency responsible for the snow and ice control program. Some states require that the largest percentage of the next year's salt requirements be placed in storage before the end of June. Others require that it be placed in storage before the end of October. Other governmental agencies rely upon the rapid resupply capabilities of local suppliers to satisfy their needs for deicing chemicals and order and stockpile these materials only on an as-needed basis.

The recommended practice is that each agency responsible for a snow and ice control program maintain under closed storage at least one-half of the seasonal requirements (and whenever possible a complete seasonal supply). Such covered salt storage should be well distributed throughout the road system in accordance with optimum operational requirements. It is further recommended that salt supplies be placed in these sheds before the middle of October or earlier depending on when the winter season begins. In addition, coordination between the supplier and the receiver should be established so that direct deliveries from the salt mine, or port of entry, will reduce the number of times the salt is handled and minimize the exposure of material to wind and moisture. In short, this means material shipments (under cover) directly from the mine, dock side, or salt-producing facility to covered storage sites for storage with minimal delay and with minimal handling and rehandling.

CHAPTER VII

RECEIVING AND STORING DEICING CHEMICALS

The three steps in receiving and storing are: 1) getting it under cover, 2) testing the material when it arrives to ensure that it meets specifications, and 3) possible mixing of various materials.

PUTTING MATERIALS UNDER COVER

Salt (Sodium Chloride)

Most highway maintenance sections have their salt supplies delivered by truck, since most are not near a railroad siding. Though the techniques listed here apply to truck delivery, they are also applicable to rail delivery.

It is desirable, though not always possible, to take delivery of salt in dry, windless weather--particularly if the storage is a tarpaulin-covered pile, or if the storage shed is not tall enough to allow a double-axle trailer dump body to raise to full height. In these cases, some exposure of salt is inevitable.

In order to minimize exposure, personnel must be prepared to put the salt under cover immediately. If salt is dumped on the pad in front of the shed, a front-end loader should be standing by to push the salt into the shed immediately. If the salt is to be stored as a covered pile, personnel should be ready with a front-end loader and suitable tarpaulin material, hand sewing machine, and weights to begin covering the pile as it is built up and shaped by the loader.

If the salt is to be mixed with calcium chloride, mixing at the time of delivery is a good idea. This will avoid extra handling, which causes the coarse and fine particles to separate out. Any salt cakes turned up during the unloading-covering process should be broken up with the loader bucket or put in the sand pile, where moisture will disintegrate them. What goes into storage must be cakefree.

When stocking storage sheds, the objective is to get the maximum amount of material into the shed with a minimum amount of work. To accomplish these ends, the largest loader available that will maneuver within the confines of the storage shed should be used.

To minimize the material pushing distance, the delivery trucks should dump as close to the stockpile as is possible. If the storage shed roof structure is too low to preclude dumping inside, then the delivery truck should dump the material close to the door. A front-end loader can then push the material into the shed and, as the pile builds, stack it as close as possible to the roof structure. The pushing windrows in the in the salt, which act as channels for the material being moved, should be cleaned up after the last load of the day has been stored. When salt is heaped inside the storage shed, the bucket hoist capability should be used rather than the pushing power of the loader to minimize shed wall loading. In sheds with high ceilings, some ramping of the salt will be necessary before maximum filling can be achieved. Caution must be exercised when the bucket is being used near the ceiling as the building may be damaged very easily when the machine is in the high-reach configuration.

As soon as the salt is under cover, the loading area is to be swept. All stray salt on trucks, loaders, or conveyors (if used) should be swept and put on the face of the salt pile so that the salt will be used during the next storm.

Calcium Chloride

Bagged calcium chloride should be stored in a dry building off of the ground on pallets or other suitable platforms that permit air to circulate under the bags. The storage should be arranged so that the first material placed in the storage is the first material withdrawn for use.

The same precautions and handling techniques used for salt should also apply to the storage and handling of bulk dry calcium chloride. Because calcium chloride is hygroscopic (readily absorbs moisture), particular precautions must be taken in bulk storage of both straight calcium chloride and dry mixtures containing calcium chloride. Whenever possible, all material should be used before the end of a winter season. However, if material remains at the end of a season, the storage of it should be arranged so that it can be used early in the next winter season before fresh stock is used.

Calcium chloride and calcium chloride-salt mixtures should also be stored in dry buildings. Piles of material should, in addition, be covered with waterproof tarpaulins or plastic film to minimize the moisture pick-up of the material on the faces of the pile. This precaution should be carefully observed, particularly for materials that must be stored during the humid summer season. Otherwise, a hard crust will form on the pile that will have to be broken up before the material can be used.

Aqueous solutions of calcium chloride should be stored in mild steel tanks that are equipped with mild steel fittings and valves. It is recommended that these storage tanks be placed at a sufficient height above the ground so that transfer of solution to the distribution tanks on trucks can be made by gravity feed, thereby eliminating the need for a pumping system. Provisions should be made in the area surrounding the calcium chloride solution storage tank for containing the contents of the tank should it fail catastrophically. This precaution can easily be incorporated into the design of a salt storage area through use of low dikes and careful grading of the area surrounding the tank so that run-off flows to a suitably sized sump. In the case of multiple liquid calcium chloride storage tanks, provision should be made for containing the spill of only the largest tank inasmuch as the occurrence of multiple failures is highly unlikely.

SPECIFICATIONS AND TESTS

The specifications outlined in this section apply to salt, calcium chloride, and mixtures of these, and to sand and cinder abrasives. Tests for the presence of anti-caking agents are also listed.

Sodium Chloride

The specification for sodium chloride generally adhered to is that of the American Society for Testing and Materials (ASTM) and designated Standard Specification for Sodium Chloride D632. The specification covers material intended for use as a deicer and for road construction or maintenance purposes. The specification covers material obtained from natural deposits (rock salt) or produced from brine (evaporated, solar, or other). Summarized below are the major requirements for this specification.

Chemical Composition - Sodium chloride (NaCl), 95.0 percent minimum.

Gradation - The gradation of Type I, sodium chloride, (used primarily as a pavement deicer or in aggregate stabilization) when tested by means of laboratory sieves, shall conform to the requirements for particle size distribution in Table 5.

Permissible Variations - In the case of sodium chloride sampled after delivery to the purchaser, tolerances from the foregoing specified values are allowed as follows:

Gradation - 5 percentage points on each sieve size, except the 1/2 in. and 3/8 in. for Grade 1 and 3/4 in. for Grade 2.

Chemical Composition - 0.5 percentage point.

In addition, individual jurisdictions may impose additional specification and delivery penalty clauses. The most commonly used specifications concern presence of moisture and anti-caking agents. Typical specifications may include one or more of the following additional clauses:

Moisture -

- Maximum 0.5% (by weight) (values to 3% reported for some states).
- Greater than 1% may be rejected (values to 3% reported for some states).

Table 5. PARTICLE SIZE DISTRIBUTION IN TYPE I SODIUM CHLORIDE
(percent weight passing)

Sieve Size	Grade 1	Grade 2
3/4-in. (19.05-mm)	---	100
1/2-in. (12.70-mm)	100	---
3/8-in. (9.51-mm)	95 to 100	---
No. 4 (4.76-mm)	20 to 90	20 to 100
No. 8 (2.33-mm)	10 to 60	10 to 60
No. 30 (0.595-mm)	0 to 10	0 to 10

NOTE: Grade 1 provides a particle grading for general application and found by latest research to be most effective for ice control and skid resistance under most conditions. Grade 2 is typical of salt produced in the Western U.S., is available in states of the Rocky Mountain Region and the West and may be preferred by purchasers in that area.

Anticake (typical clauses) -

- Not more than 100 mg/1 sodium ferrocyanide (0.01 percent by weight).
- Not less than 0.04 lb of pure anti-caking agent per ton of sodium chloride (20 mg/1).
- Not more than 0.5 lb of conditioner per ton of sodium chloride (250 mg/1).
- A certificate must be submitted giving the trade name of the conditioner and the address of the manufacturer.
- Non-caking additive added.
- The sodium chloride shall be treated with an anti-caking material prior to delivery.

Delivery -

- All sodium chloride must be covered during transit with a tarpaulin or other suitable material and delivered in a dry condition.

Calcium Chloride

Flake calcium chloride (Type 1) is the preferred deicing chemical. It contains between 77% and 80% calcium chloride and about 20% water of crystallization. The most commonly used specification for calcium chloride is ASTM Specification D-98. Two types of calcium chloride are covered: Type 1 - regular flake calcium chloride - and Type 2 - concentrated flake, pellet or other granular calcium chloride. Pertinent information contained in these specifications is summarized in Tables 6 and 7.

Pre-Mixed Sodium Chloride and Calcium Chloride

At this time, there is no established specification for pre-mixed sodium chloride and calcium chloride material for highway deicing. Typical formulations range from five parts sodium chloride and one part calcium chloride (16.6% mixture) to a mixture of three parts sodium chloride and one part calcium chloride (25% mixture).

The basic ingredients of a specification are outlined below:

- The materials shall be throughout, a completely uniform and free-flowing blend of the two ingredients. Mixing can be achieved by any means suitable to produce the desired uniform mixture.

Table 6. CHEMICAL COMPOSITION REQUIREMENTS FOR CALCIUM CHLORIDE

	Percent	
	Type 1	Type 2
$CaCl_2$, minimum	77.0	94.0
Total alkali chlorides (as NaCl), maximum	2.0	5.0
Total magnesium as $MgCl_2$, maximum	0.5	0.5
Other impurities (not including water), maximum	1.0	1.0

Table 7. PARTICLE SIZE REQUIREMENTS FOR CALCIUM CHLORIDE

Sieve size	Percent passing (by weight)
3/8-in. (9.51-mm)	100
No. 4 (4.76-mm)	80 to 100
No. 30 (o.595-mm)	0 to 5

- The sodium chloride shall conform to ASTM Specification D-632.
- The calcium chloride shall conform to the requirements of ASTM Specification D-98, Type 1 or Type 2.
- The stipulated quantity of calcium chloride by weight of the mixture with sodium chloride shall be a minimum quantity. Any minus deviation on calcium chloride will be subject to material rejection or assessment of damages.

Calcium Chloride Solutions

No specification has been established for calcium chloride solutions. The standard test for determining the percentage composition of calcium chloride in aqueous solution is to measure the specific gravity of the solution at room temperature with a suitable hydrometer. Summarized in Table 8 are the percentage compositions of calcium chloride by weight in solutions of calcium chloride at room temperature with various specific gravities.

Table 8. PERCENTAGE COMPOSITION BY WEIGHT OF CALCIUM CHLORIDE SOLUTION

	Percent by Weight	
Specific Gravity at 20°C (68°F)	Hydrated $CaCl_2 \cdot 2H_2O$ Type 1	Anhydrous ($CaCl_2$) Type 2
1.008	1.32	1.0
1.017	2.65	2.0
1.025	3.97	3.0
1.033	5.30	4.0
1.042	6.62	5.0
1.051	7.95	6.0
1.059	9.27	7.0
1.068	10.60	8.0
1.077	11.92	9.0
1.085	13.25	10.0
1.103	15.90	12.0
1.122	18.55	14.0
1.141	21.20	16.0
1.160	23.84	18.0
1.180	26.49	20.0
1.200	29.14	22.0
1.220	31.79	24.0
1.241	34.44	26.0
1.262	37.09	28.0
1.284	39.74	30.0
1.306	42.39	32.0
1.328	45.04	34.0
1.351	47.69	36.0
1.375	50.34	38.0
1.398	52.99	40.0

Sand

Abrasives should be clean and hard with 100% passing a 0.5-in. (1.3-cm) screen, and the minimum size should be retained on a No. 50 mesh. Larger particles could damage passing vehicles, and smaller particles are of no use in increasing the coefficient of friction and also retain moisture and freeze. Cinders should be free from large uncrushed particles. Depending on local conditions, abrasives should be mixed with salt or calcium chloride, approximately 5% by weight, at the time of stockpiling to keep the pile from freezing.

Tests for Presence of Anti-caking Agents

The two most common anti-caking additives in highway salt are ferric ferrocyanide, $Fe_4(Fe(CN)_6)_3$ (Prussian Blue), and sodium ferrocyanide, $Na_4Fe(CN)_6 \cdot 10H_2O$ (Yellow Prussiate of soda-YPS). The presence of ferric ferrocyanide can be detected by visual inspection of the salt for a blue tint.

The presence of sodium ferrocyanide in deicing salt can be detected by squirting a dilute aqueous solution (1%) of ferric chloride from a squeeze bottle onto the salt. The material dampened by the solution will turn blue (Prussian Blue reaction), indicating the presence of sodium ferrocyanide.

BLENDING MATERIALS

Should the operation require blends of various deicing and anti-skid materials, a decision must be made as to whether to purchase material blended to specification or to mix it on the site. In general, the major salt suppliers will blend salt-calcium chloride mixtures at a lower cost than can be accomplished on site. Some of the suppliers are equipped with conveyor systems that mix and load in one operation.

Since salt-calcium-chloride mixture is usually delivered as premix and handled as straight salt (though with even more careful attention to keeping it dry), the main source of concern is sand-salt. Premixing is desirable when this mixture is used in preference to straight salt--for example in climates with frequent temperatures below 10°F (-12°C)--so that spreaders can be loaded more quickly. The same precautions apply as for straight salt. The pile must be kept dry--water on a sand-salt pile during mixing or afterward will leach out the salt.

There are two basic ways of mixing salt or calcium chloride with sand. One is to prepare a "premix" pile that is transferred directly to the spreader trucks. The other is to keep the piles of material separate until the trucks are ready to roll in a storm, then load the desired portions (a scoop of salt, three of sand), onto the trucks.

On-site mixing of $NaCl-CaCl_2$ and salt/sand blends may be accomplished by spreading a layer of sand or salt on a paved pad, then adding a layer of the second component. This material is then picked up and put into the stockpile. Subsequent loading and spreading operations continue the mixing action.

A second on-site mixing technique which is simpler, and which most proponents believe just as effective, is to partially fill the spreader hopper with sand (about 1/2), add a layer of salt to give the correct mix, then fill the hopper completely with sand. The action of the conveyor flight bars (after the short initial discharge of unmixed sand) tends to mix the salt and sand as the material falls onto the flight bars. (See Figure 29.)

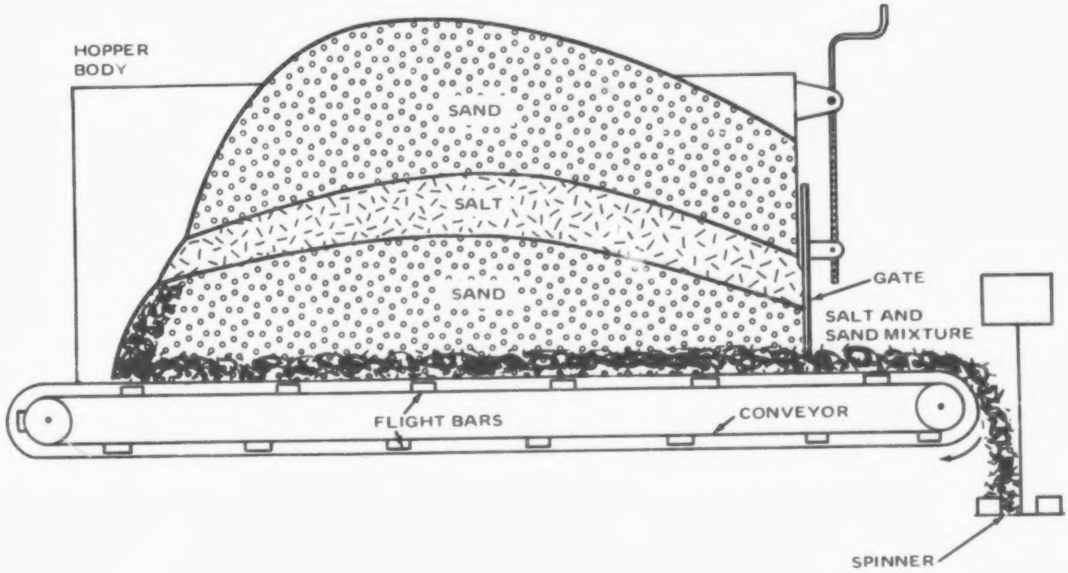


Figure 29 Mixing of salt and sand by flight bars in spreader hopper

As a result of the large quantities often used, chemically treated sand is usually stored out of doors and uncovered. This practice should be avoided if there is sufficient covered storage available for the quantities required. However, first priority should be given to storage of bulk salt and calcium chloride under cover.

Precautions that should be taken to minimize the amount of chemical leached out of chemically treated sand piles include:

- Pre-mixing treated sand as late as possible prior to the winter season will minimize exposure of the sand-salt pile to fall and early winter rains.
- Periodic mixing of chemically treated sand can occur during the winter by taking advantage of thawing conditions when an untreated sand pile can be worked. Periodic mixing also tends to minimize the amount of material left over at the end of the winter season.
- Minimizing the amount of chemical used in treating sand piles is important. Only enough chemical is mixed into the sand piles to prevent them from freezing. The recommended mixture is 80 lb of sodium chloride to 1 ton of sand (4% mixture).
- Covered stock piles of chemically treated sand should be placed on a bituminous concrete pad that is of sufficient size and is sloped so that water runs away from the pile. In this way, no water will flow through or around the pile and only precipitation enters the pile.
- Chemically treated sand that must remain exposed to the weather for periods longer than one month (such as that remaining at the end of the season) should either be removed to a covered shed or suitably covered with tarpaulins, plastic film, or reinforced plastic film and secured against wind damage.
- Continual cleaning up is essential around the area during and after periods when chemically treated sand is being withdrawn from the stockpile. Good housekeeping practices should be employed at all times and spilled material should be cleaned up after every storm.

CHAPTER VIII

LOADING CHEMICALS FOR USE

The procedures described in this section apply to the loading of bulk salt or calcium chloride onto trucks, either for shipment to another destination (i.e., from mine to a regional stockpile, or from there to a maintenance yard) or for spreading on the highways.

If possible, loading of trucks or spreaders should occur inside the salt storage shed. This reduces spillage and cleanup problems. If the salt or premix is stored in covered windrows, only as much of the pile exposed will be loaded. When loading occurs outside, a loading ramp such as the one shown in Figure 30 may be useful. (The design for such a ramp is shown in Chapter III of this manual.)

Spreader trucks should be loaded with minimum loader cycle time consistent with safe equipment operation. This is accomplished by using a minimum number of direction reversals and turns and the shortest path possible. The loading pattern should be designed so that the spreader truck driver can observe the loader during loading operations. If possible, backing up of the spreader truck should be avoided. Typical loading patterns are shown in Figures 31-33 for several shed configurations.

If possible, it is best to use the oldest material first. This is possible in a shed with front and rear doors or in a covered windrow. In a one-door shed, new material may be dumped in on top of the old. If the shed is good and dry, not being able to get the old material out of the back is not so important--it will not lump, and it is better to leave it alone than to move it around to make way for new material.

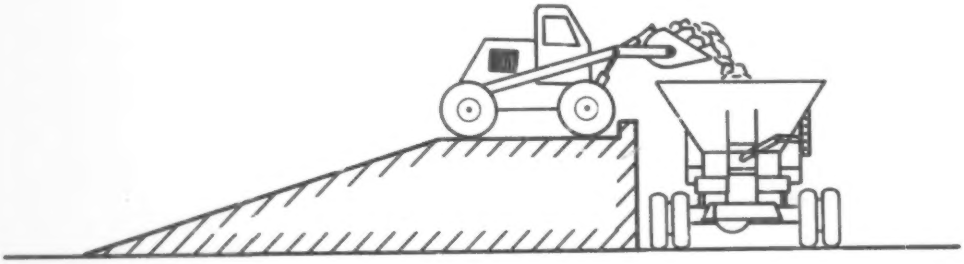


Figure 30 Loading ramp

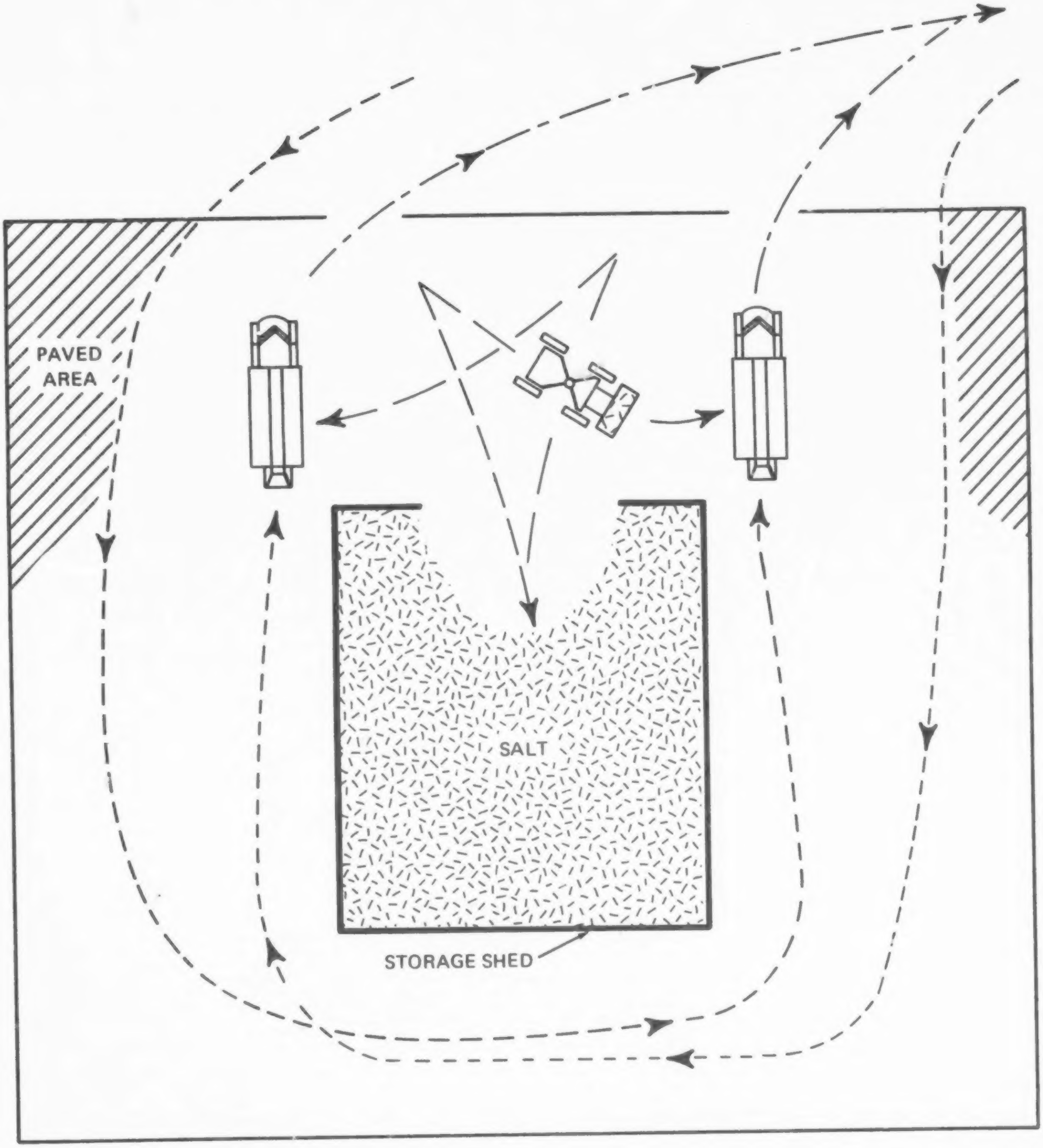

PAVED AREA
SALT
STORAGE SHED

Figure 31 Typical loading pattern for a storage building with one entrance

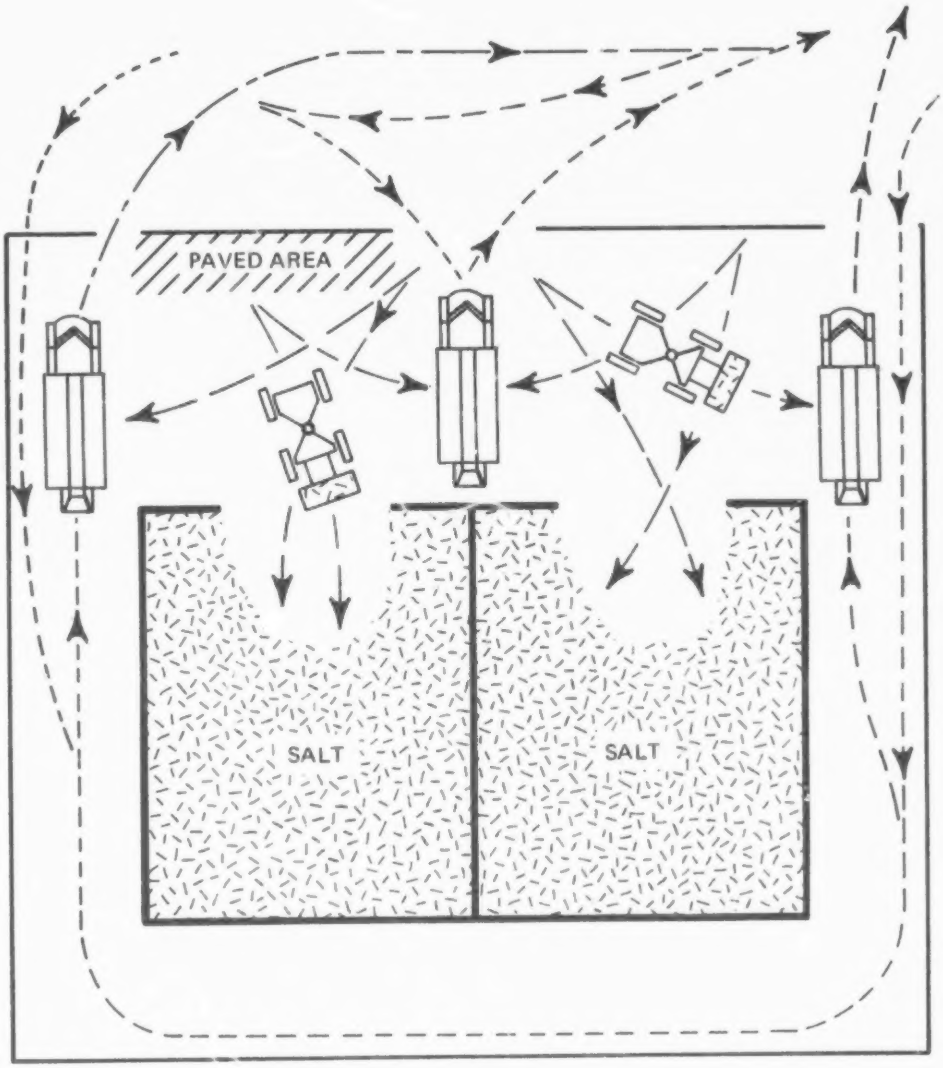

PAVED AREA
SALT
SALT

Figure 32 Typical loading pattern for a storage building with two bays

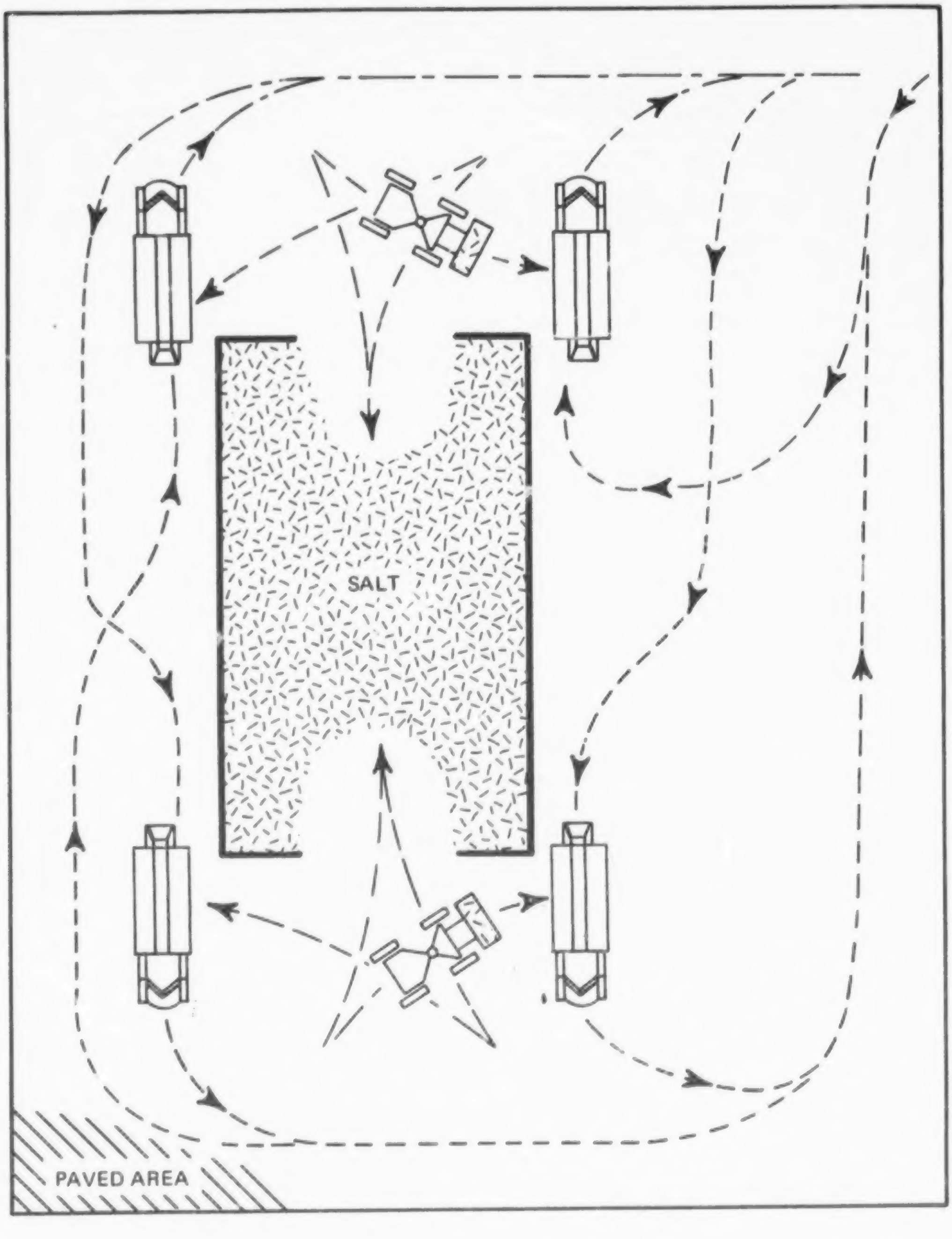

SALT
PAVED AREA

Figure 33 Typical loading pattern for a storage building with front and rear entrances

If calcium chloride is to be mixed with salt during the loading operation, a quantity of calcium chloride sufficient to last throughout the storm should be put into the corner of the salt storage shed. It can then be handled under cover. To prevent spillage from truck side way, hoppers should be filled only to the level of the screen.

Before the truck leaves the shed or loading area, it should be cleaned--catwalks, top edges and ledges of the body, tanks, roof, and fenders. This will keep the salt from spilling off where it's not wanted. The screen also should be checked for lumps--these may stop the flow or jam the spreader. The lumps are to be broken or thrown in the sand pile, not abandoned. (With proper precautions taken earlier, salt should be dry and lumpfree.) The driver should log the load, visually check out spreader and truck (lights, tires, etc.), and then start out on his route.

Once the truck leaves, the loader operator should clean up the loading area in preparation for the next truck. All spilled salt in the loading area should be scraped up and put back on the face of the pile. This is important in sheds and on and around loading docks to keep piles and lumps from restricting the wheel movement of the trucks and loader. In open loading areas, cleanup is important to minimize the amount of salt that gets wet. Wet spills should be scooped into a heap at the base of the pile to go out on the next truck. If the loader operator has to wait for another truck, he should put his machine into the shed to keep it from getting wet.

In summary, the least wasteful storage handling of salt can best be accomplished by thoughtful planning and the exercise of reasonable care in handling.

ANNOTATED REFERENCES

1. Hogbin, C.E., Road Research Laboratory, Ministry of Transport, Loss of Salt due to Rainfall on Stockpiles Used for Winter Road Maintenance, Harmondsworth Road Research Laboratory (U.K.), Ministry of Transport RRL Report No. 3, 1966, 4 pages.

   This report describes measurements made to find the losses due to rainfall on large stockpiles of salt used for preventing the formation of ice on roads, and assess the value of providing covers. It is concluded that covering becomes economical when the annual rainfall exceeds about 24 inches, that is over all the United Kingdom except the East and Southeast of England, where the saving would be marginal. Covering also keeps the salt dry so that it can be handled easily and spread evenly on the road by machine. Even spreading allows a lower rate per square yard to be used.

2. Richardson, D.L., Terry, R.C., Jr., et. al., Arthur D. Little, Inc., Cambridge, Massachusetts, Manual for Deicing Chemical Application Practices, Environmental Protection Agency Report No. EPA-670/2-74-045, 1974.

   This manual contains the results of a study conducted for the U.S. Environmental Protection Agency to minimize the use of chemicals in controlling snow and ice on highways. Based on the best current practices for highway maintenance as observed during two years of study, practical guidelines are presented for control and removal of ice and snow from highways by plowing and through the use of salt, calcium chloride, abrasives, and combinations thereof. Included are discussions of administration and supervision of snow and ice control operations; the role of weather forecasting and other inputs to decisions made during winter storms; tabulations of recommended quantities of chemicals to be applied to various classifications or roads; recommended levels of service; operation procedures; methods for accounting for usage of deicing chemicals; descriptions of equipment including ground-speed-controlled spreaders, plows, trucks, and other snow-removal equipment; discussions of techniques for calibrating and checking the calibration of chemical spreaders; and discussions of how public administrators and highway maintenance personnel can interact with the driving public and environmental and conservation groups.

3. Pletan, R.A., Maintenance Methods Engineer, Maintenance Standards Section, Minnesota Highway Department, Salt Brine Runoff Control at Stockpile Sites, St. Paul Minnesota: Office of Engineering Standards, Research and Standards Division, Minnesota Highway Department, November 1972, 18 pages.

> This report summarizes the results of a study of salt brine pollution undertaken by the Maintenance Standards Section of the Minnesota Highway Department. Over 85 sites of salt and treated sand stockpiles were examined, with special emphasis on those in which salt brine runoff currently caused pollution or could do so in the near future. The extent of the problem of salt brine runoff was analyzed, and possible solutions were evaluated. Finally, a course of action was recommended for the Department, including time tables and costs.

Although not cited in this manual, the following publications are also of interest.

Cohn, M.M., and Fleming, R.R., American Public Works Association, Managing Snow Removal and Ice Control Programs. A Practical Guide to the How, When, Where and Why of Effective Public Work Practices. American Public Works Association Special Report No. 42, 1974, 168 pages.

> A collation of papers presented at the Annual North American Snow Conferences 1969-1973, this document is a manual of practice presented through on-the-job accounts of leading authorities. The manual covers preparations before the storm, performances during the storm, practices and problems in chemical-abrasive treatment of ice and melting methods, and post-storm evaluations of performance and productivity.

National Cooperative Highway Research Program. Minimizing Deicing Chemical Use Synthesis of Highway Practice No. 24, Transportation Research Board, Washington, D.C., 1974.

> With the premise that it is possible to reduce the use of chemicals and still provide a satisfactory level of servive on streets and highways, this report presents the results of an investigation of minimizing the use of deicing chemicals. Suggestions are given for approaches to reducing chemical usage through careful planning of snow removal equipment assignment and routes, timing of chemical applications, spreader metering devices, relating rates of application to storm conditions, use and control of application equipment, more dependence on mechanical snow removal, operator training and delineation of a management philosophy of winter maintenance.

Terry, R.C., Jr., Arthur D. Little, Inc., Road Salt, Drinking Water, and Safety: Improving Public Policy and Practice, Ballinger Publishing Co. Cambridge, Massachusetts, 144 pages.

This policy study, written initially for the Commonwealth of Massachusetts in 1972, was greatly expanded in 1973 to report developments in research, improvements in managerial and technical practices of highway departments, and important legislative developments in both the United States and Canada. It synthesizes the data now available from the fields of chemistry, sanitary engineering, road maintenance, public health, medicine, and administration.